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NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY PROF. CHAS. E. MUNROE, U. S. N. A.

Among the curious applications of the high explosives is their use in clearing out the obstructions in blast furnaces which are still in operation. An account of this use of them is given in the *Transactions of the American Institute of Mining Engineers* for October, 1881, by Mr. T. F. Witherbee. Owing to some irregularity in working the furnace a thick pasty mass filled the tuyere circle, stopping the tuyeres and threatening the furnace with freezing. In this emergency, after trying in vain to dig out the mushy material, a hole was driven in the mass, and a 5-inch pipe, with an end welded in, was packed in the hole with clay and cooled by a stream of water injected into it. The cartridge consisted of a piece of 3½-inch gas-pipe, plugged with wood at each end and loaded with thirteen ordinary 1¼-inch Rend-rock cartridges. This was shoved into the 5-inch case, tamped or sealed with a ball of clay, and fired with all possible dispatch, as the 5-inch case was red hot. It failed to explode, as also did a second one, and the powder, on examination, was found to be worthless. Two days after a hole was worked back two feet into the furnace, charged with twenty-five Atlas cartridges, and exploded without doing the furnace any appreciable damage. Before loading, a test was made to ascertain the danger, by putting a handful of powder into a dry pine box, similar to the cartridge case to be used. It remained three and a half minutes in the hole before it ignited, showing that there was but little risk, especially as the real cartridge case was wet and coated over with blue clay.

*As it is proposed to continue these notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars.

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Under the title, "Scaffolds and Engorgements in Blast Furnaces," a summary of various methods of using explosives, etc., in removing them is given in the *School of Mines Quarterly*, III, 4, 304.

In the same Quarterly, 296, it is stated that Nobel's Blasting Gelatine and Gelatine-Dynamite have proved very efficient in the St. Gothard tunnel. The principal fact established during the use of these explosives is that the relation between the blasting gelatine and Nobel's common dynamite is about three to five. Gelatine dynamite has more of a pushing than a breaking effect, and is hence advantageously applicable to quarries, and on the whole its effect and economic value is about the same as that of common dynamite. With the stronger of the new explosives, blasting gelatine, where boring is expensive, the same work may be accomplished with the boring of three holes, as with five holes charged with common dynamite. The gases from both gelatine dynamite and blasting gelatine did not inconvenience the workmen, even immediately after the blast.

In the same Quarterly, 250, will be found an account of the accidents due to explosives at the mines in the Marquette iron region.

Major Lauer claims that his method of pulverizing rocks in the beds of rivers by exploding dynamite on their surface leaves them in a condition to be removed by the current. Cartridges inserted in drill-holes break them in large fragments, requiring mechanical removal often at great cost.—(*Journal Franklin Institute*, 678, 451.)

"Dynamite and its Manufacture" is the title of a lively and popular description of the works at Ardeer, in Ayrshire, and the processes employed there. As it is announced as the first of a series of articles, it will be noticed hereafter.—(*Engineering*, March 10, 1882.)

Both *Engineering* of Nov. 25 and *The Engineer* of Dec. 2, 1881, give a lengthy account of a recent gathering at the Stowmarket Explosives Works, to witness the trial of their products, among which were the new gun-cotton sporting powder and a new form of dynamite. The articles open with descriptions of the manufacture of the ordinary gun-cotton, that in *The Engineer* being quite full and accompanied by drawings and data. According to *Engineering*, the new gun-cotton powder or rifle gun-cotton is not submitted to any pressure, the gun-cotton proper being incorporated under metal

rollers with another material, the nature of which is kept a secret; it is then roughly granulated in perforated revolving zinc drums, and eventually passed through a sieve suited to the size of grain desired. In appearance this new powder is of a bright yellow color; the grains are about the size of those of ordinary sporting powder, and extremely uniform both in size and shape. It is quite water-proof, and may be placed for months under water without injuring its qualities. *The Engineer* says: "This sporting or rifle powder is made of a combination of gun-cotton with nitrates of soda and potash, being in fact very nearly Mr. Abel's nitrated gun-cotton. The grain appears hard and firm, comparing favorably with Schultz's powder, and it is glazed, so that it may be thoroughly wetted and dried again." It is claimed that a given weight of this material is equal in explosive force to nearly three times the quantity of gunpowder, while at the same time the recoil is very slight, and there is no smoke and but little noise. When cartridges of this powder were fired from a Martini-Henry rifle, or 12-bore double-barreled fowling piece, the recoil could not be felt, and the report was no louder than that of a percussion cap. The penetration with thirty grains equalled that of eighty-one grains of violent sporting powder. There was scarcely any perceptible fouling of the barrel and no deposition of solid refuse. *The Engineer* does not think, however, that we are yet warranted in adopting gun-cotton cartridges for use with bullets, and it holds that a very extensive series of firing trials should be successfully carried out before we use it.

The new dynamite differs from ordinary dynamite in its absorbent, which is said to take up six times its weight of nitroglycerine and hold it without exudation or oxidation, while it is itself an explosive. The ingredients are at present a secret, but specimens of the new dynamite and of Nobel's were shown in water. The latter had exuded nitroglycerine, while in the former there were no signs of it. It is claimed, also, that the freezing-point of the new dynamite is lower than that of Nobel.

Experiments were made with gun-cotton to show its use as a military explosive, and $\frac{1}{4}$ -ounce charges of gunpowder, Nobel's dynamite, the new dynamite, mining gun-cotton (a nitrated cotton), and pure gun-cotton (known as torpedo cotton), were tested by Colladon's* lead-cylinder test and the steel disk test, the results being about in the order given. Eighty steel rails were broken by detonating seven

* Proceedings Nav. Inst., Vol. V, p. 25.

ounces of dry cotton, with one ounce of dry cotton used as a primer. A tree was cut in two by a ring of gun-cotton pellets placed round it. Lastly, a weight of two hundredweight was dropped ten feet on a box containing five pounds of dry gun-cotton pellets without firing any of them. The cotton, which was crushed and broken by the fall, was proved to be dry by the ignition of some pellets by a match, when they readily burnt.

The steel-disk test is illustrated by drawings in *The Engineer*. It consists of a steel cylinder two inches in diameter, with walls one-fourth inch thick, in which a shoulder is cut at the top for the support of the steel disk, which is one-fourth inch in thickness. The explosive is placed on the disk and exploded, and it bends the plate into a cup of different depths, or breaks it, according to its strength. With twenty grams of new dynamite, or twenty grams of mining gun-cotton, holes were punched through these $\frac{1}{4}$ -inch disks. Holes of small size were also punched through steel plates five-eighths inch thick with seven ounces of the new dynamite, and through steel plates fifteen-sixteenths inch thick with 14 ounces of the same material. The effect on tough wrought iron would probably be slightly less, but some of these experiments suggest punching plates with fulminate of silver or other such severe explosives, instead of by machine.

In speaking of the gun-cotton powder, *Engineering* says: "The absence of recoil can only be accounted for on the supposition that the charge burns slowly and progressively, thus maintaining a pretty uniform pressure throughout the whole length of the barrel." This explanation is warmly contested in letters to this journal of December 9 and 23, 1881, and January 20, 1882. *The Engineer*, speaking on the same subject, says: "The absence of smoke is an advantage justly claimed for gun-cotton. The decrease in noise is very well as far as it goes, but the absence of recoil is a more questionable matter, implying that the work done on the piece is more local and sudden, and therefore more dangerous to the piece. At the Royal Arsenal, in testing gun-cotton some years ago, as the conditions became more satisfactory, a recoil was produced."

On this subject W. T. Reid, the chemist to the works, in a letter to *The Engineer*, December 16, 1881, says: "You remark with reference to the new sporting-powder, 'The absence of recoil is a much more questionable matter, implying that the work done on the piece is more local and sudden, and therefore more dangerous to the piece.'

As the inventor of the powder, I should like to add a few words on this important subject of recoil. The method usually adopted for measuring the recoil of small-arms is to fix the gun or rifle in a frame provided with an apparatus for registering the recoil of the whole weapon. This method is, for the reason you have given, defective, and the results necessarily erroneous, as a charge of gun-cotton, dynamite, or other powerful explosive sufficient to burst the barrel might be detonated in it without producing more recoil than ordinary black powder. To obviate this difficulty, we now always estimate the recoil by means of a machine in which the pressure at the base of the cartridge itself is registered. Tested in this way I have found that the strain on the base of the cartridge, and consequently on the breech of the gun, is, in the case of the new powder, about one-quarter of that exerted by ordinary black sporting-powder, while the penetration at fifty yards in each case is the same. It appears from this that the powder required to propel the shot at the velocity produced by the usual charge of black powder need not necessarily cause the same strain on the breech of the gun.

“It may interest some of your readers to know the method we have adopted to secure the penetration of the shot from ordinary sporting-guns. Refined paraffine wax, of a definite melting-point, is cast into a block about two inches thick, and the penetration of the shot into this block is measured. The paraffine is kept at a uniform temperature of 54° F. by means of the water from the artesian well. This method has the additional advantage of permitting the recovery of the shot intact, their shape being to some extent an indication of the intensity of the explosion. When fired with dynamite or pure gun-cotton, for instance, the shot lose their spherical shape and are converted into polygons, which can be recovered uninjured by melting and pouring off the paraffine.”

The Stowmarket Explosives Company has now become the Explosives Company, Limited, and has acquired 150 acres of land at Pembrey, near Swansea, where it will manufacture its nitroglycerine and gun-cotton compounds.

The rapidity of inflammation and combustion and of the transmission of detonation in explosives is a subject of great interest and practical importance, which has been but little studied for other

explosives than gunpowder. Abel has measured the rate of transmission of detonation for wet and dry gun-cotton, and Bunsen estimated the same constant for certain gaseous mixtures. The gaseous state seems to offer the best facilities for the study of this phenomenon, and the matter has been taken up in this form by Berthelot and Vieille, who have presented their results in a series of articles in the *Comptes Rendus*. These are entitled "On the velocity of the propagation of explosive phenomena in gases," XCIII, p. 18, and XCIV, p. 101; "On the explosive wave," XCIV, p. 149. The experiments were made by filling an iron tube, 8 mm. in internal diameter, with the gas, and exploding it at one end by means of a small electric spark. At accurately measured intervals in the tube diaphragms of thin tin were placed and connected with a Le Boulengé chronograph. To the tin were fixed small masses of fulminating mercury or picrate of potash, which were exploded by the wave, destroying the tin and breaking the current. About .01 of the gram of fulminate, or .006 of a gram of picrate, was used. The latter was employed because it is quite insensitive to a blow, is totally insensible to sonorous vibrations, and does not ignite below a temperature of 300°. The results were the same with both. The mixtures used were H and O, and CO and O, two volumes of the first to one of the second being taken in each case. In the earlier experiments the tube was but five metres in length, but as the velocity was found to be so great that the error of observation became very large, a tube over 40 metres in length was used. With this instrument it was found that the velocity of propagation in a mixture of H and O was 2810 metres per second, and in CO and O 1089 metres per second. A large series of experiments led to the conclusion that the velocity was independent of the position of the tube, of the material of which the tube was made, of the condition of the tube as to its being open at one end or both ends or closed at both ends, of the length of the tube, and of the pressure, but that the addition of an inert gas retarded the propagation. The fact that the flame was retarded by condensing water while the wave was still propagated, illustrates the difference between progressive combustion of a gaseous mixture and of detonation. Berthelot holds that these experiments reveal the existence of a new species of undulatory movement, of a mixed order, which is produced in virtue of a certain concordance of physical and chemical impulses developed through the transformation of matter. In a word, it does not act like a sound wave, transmitted from particle to particle with a velocity determined

only by the physical constitution of the vibrating medium—a velocity which is the same for all vibrations. On the contrary, it is the change of chemical constitution which propagates the wave. The velocity of the explosive wave is also entirely different from that of the sound wave in the same medium. While the velocity of sound in the mixture of H and O is 514 metres at 0° , that of the explosive wave is 2841 metres. The velocity of sound in the CO and O is 328 metres, and in the CO_2 produced 264 metres, while the velocity of the explosive wave is 1089 metres.

It is difficult to establish the theoretical relation which ought to exist between the velocity of the explosive wave and the chemical nature of the gas which transmits it, as this depends upon the temperature, and it is not the same in the combustion of the two different systems. The inequality of temperature results from the great difference in the total heat (that for $\text{CO} + \text{O}$ being 68,200 and for $\text{H}_2 + \text{O}$ 59,000, supposing the water in the gaseous state), and besides, we are uncertain both as to the specific heat of these high temperatures and to the condition of the gas as regards dissociation. However, we may partially comprehend the theoretical relation governing the velocity of the explosive wave, if we observe that the total energy of the gas at the moment of explosion depends on the initial temperature and the heat disengaged during the combination; these two being given, we can determine the absolute temperature of the system, which is elsewhere proportional to the energy of translation of the gaseous molecules. Using Clausius' well-known formula,

$$v = 29.354 \text{ metres } \sqrt{\frac{\tau}{\rho}}$$

and letting τ , the absolute temperature, equal 3000° , Berthelot finds that the velocity of translation of the gaseous molecules, at the temperature of the experiment, would be practically the same as the velocity of the propagation of the wave measured in the experiments. [Notes on these papers will be found in *The Engineer* for Feb. 10, March 8, April 7, and May 19, 1882, and July 29, 1881.]

About the time that Berthelot undertook this work, Messrs. Mallard and Le Chatelier entered independently on a similar investigation, the results of which are given in the *Comptes Rendus*, XCIII, p. 145, under the title, "On the velocity of propagation of the inflammation in mixtures of explosive gases." The apparatus employed differed from Berthelot's, in having a small lateral tube attached to each

end of the main tube. The ends of these lateral tubes were closed by a membrane, on which an index rested. When the detonation took place the membranes were stretched and the index moved. They worked with mixtures of the detonating gases with other gases, and of course got lower results than Berthelot obtained in the molecular mixture. The one exception was a mixture of $\text{CO} + \text{O}$, when they obtained the singularly low velocity of 2.2 metres. Again, they worked with very short tubes, the longest one cited being 1.35 metres long. They hold that the velocity of propagation is greater when the gas is ignited at the closed end of the tube than when it is fired at the open end, and conclude that this is due to the enormous expansion of the products of combustion. They hold also that the velocity increases as the flame advances, that the velocity increases with the temperature, and that the diameter of the tube has no influence on the velocity except in exceedingly small tubes.

In pursuance of his investigations in thermo-chemistry, Berthelot has taken up the subject of the detonation of endothermic substances, and gives some of the results in the *Comptes Rendus*, XCIII, 613, under the title, "The detonation of acetylene, cyanogen and endothermic substances in general." Although neither acetylene, cyanogen nor nitric oxide can be detonated by simple heating, contact with a flame, or the electric spark, yet it was found that the detonation of a small quantity of fulminate of mercury would instantly detonate them. The study of explosive matters presents analogous phenomena, for while with dynamite, for instance, simple inflammation is insufficient to provoke detonation, this is effected under the influence of special detonators, like fulminate of mercury, which gives rise to a very violent blow. This is due, as shown above, to the development of an explosive wave. Berthelot holds that the superiority of fulminating mercury as a detonator is not due solely to the rapidity of its decomposition, but is due in a great measure to the enormous pressure which it develops in detonating; a pressure greater than that of any known body, and which he estimates, from his experiments, to be equal to 40,000 kg. per square centimetre.

Endothermic substances may be exploded by a blow at the ordinary temperature if the volume is sufficiently reduced, as in the case of nitric oxide and oxygen, which exploded by a blow after its volume had been reduced to $\frac{1}{500}$ of its original volume, and then evolved 20,300 units of heat. As the temperature rises they become more

sensitive to blows, and hence it has been observed several times that celluloid, which is ordinarily a very stable body, has exploded when it has been struck a blow after it was heated to the temperature at which it could be moulded.

The new study, known as thermo-chemistry, is one with which the student of explosives must become familiar. It has been developed during the past twelve years through the independent labors of Thomsen of Copenhagen, and Berthelot of Paris. Until three years ago the only information to be obtained on the subject was through reading the numerous papers of these investigators and their pupils scattered through various scientific journals. In his "Essai de Mécanique Chimique fondée sur la Thermo-chimie" (Paris, 1879, 2 vols.), Berthelot has gathered together, in a systematic form, the fruits of his labors up to the time of publication. The subject has been ably reviewed by Prof. J. P. Cooke (*Am. Jour. Science*, XIX, 261), and the same author has given a résumé of the subject, with its application to explosives, in the recent edition of his "Chemical Philosophy" (1881).

To put it briefly, thermo-chemistry is the study of the thermal changes which accompany chemical changes. One of the simplest illustrations of this is found in the ordinary processes of combustion. When the atoms unite in these cases heat is evolved. It was for a long time generally believed that heat was evolved in all cases of chemical union, but we now know of many such cases which are attended by the absorption of heat. Owing to this fact chemical compounds have been divided into two classes, exothermous bodies, or those which evolve heat during their formation, and endothermous bodies, or those which absorb heat during their formation. One of the most remarkable compounds of the latter class is the chloride of nitrogen, which evolves 38,100 units of heat when it is decomposed. Another is nitric oxide.

This last substance has been made the subject of a recent investigation by Berthelot, in a contribution to the *Comptes Rendus*, XCIII, 668, under the title, "Nitric oxide as a supporter of combustion." Since nitric oxide contains more than 50 per cent. of oxygen, and since this oxygen in combustion disengages 21,600 more units of heat than free oxygen, it ought to be a more active supporter of combustion than free oxygen. It is known in practice, however, that the temperature of the combustible must be raised very high before the

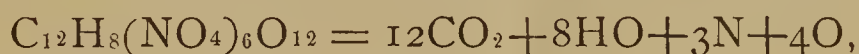
reaction takes place. Berthelot finds this to be due to the formation of nitric peroxide, which is only decomposed at a high temperature. The reason why the carbonic oxide developed from the mercuric fulminate (alluded to in the preceding paper) burns so suddenly in nitric oxide, is because the oxygen of the nitric oxide is set free all at once by the fulminate without passing through the stage of peroxide. (See also abstract in *Journal Chemical Society*, CCXXXII, 264.)

Under the title, "The heat of the formation of explosive substances," (*Comptes Rendus*, XCIII, pp. 213 and 269), Sarrau and Vieille describe their method of research and give some results. As the nature of the products varies with the pressure, they were obliged to analyze the products in each case, while measuring the heat developed. Knowing then the heat of formation of each of the products, they could calculate the heat of formation of the explosive used. The explosion was produced in a wrought-iron vessel of about 300 cm. capacity, immersed in a copper calorimeter containing 1.8 kilos of water. For nitroglycerine the heat of decomposition was found to be 1600 units of heat per kilogramme, when the reaction was



and the heat of formation of one equivalent 94.

For nitromannite 1512 units per kilo. and the reaction



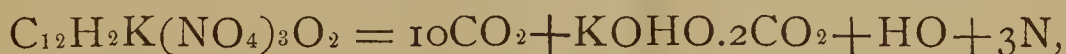
and the heat of formation for one equivalent 161.5.

For gun-cotton 1070.7 units per kilo. and the reaction



and the heat of formation for one equivalent 639.5.

For picrate of potash 2329 units per kilo. and the reaction



and the heat of formation for one equivalent 117.5.

For picrate of ammonia, $\text{C}_{12}\text{H}_2(\text{NH}_4)(\text{NO}_4)_3\text{O}_2$, 2818 units per kilo., and the heat of formation of one equivalent 80.1.

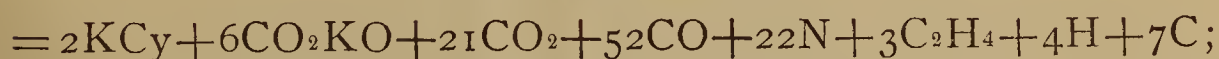
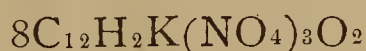
Berthelot and Vieille contribute a paper to the *Comptes Rendus*, XCIII, p. 289, on "The heat of formation of potassic perchlorate," which they find to be —112.5 units of heat.

In the *Comptes Rendus* for May 10, 1880, Sarrau and Vieille have given the results of their investigations upon the nature and volume

of the gas formed by the explosion of different explosives in closed vessels, and they have pointed out for gun-cotton that the reaction which attends the deflagration and the mean density of the products vary when increasing weights of the material are deflagrated in the same closed vessel. They have extended their researches to picrate of potash, and give the results in the *Comptes Rendus*, XCIII, No. 2, under the title "Experimental researches on the decomposition of picrate of potash; analysis of the products." The same general result is shown here as in the case of gun-cotton. The composition and volume of the gas, under normal conditions, with different charges, is given in the following table:

Mean density of products,	. . .	.023	0.3	0.5
Hydrocyanic acid (cyanide of ammonia),		1.98	0.32	0.31
Carbonic acid,		10.56	13.37	20.48
Carbon protoxide,		62.10	59.42	50.88
Marsh gas,		0.17	2.38	5.39
Hydrogen, (?)		10.31	6.77	2.68
Nitrogen,		16.88	17.74	18.26
Volume of gas in litres,		574.1	557.9	

We observe from this table that, as in the case of gun-cotton, the transformation from carbon protoxide to carbonic acid, under increased pressure, depends upon the vapor of water, but the hydrogen liberated passes into marsh gas. The experiments made with a density of 0.5 may be represented by the reaction,



but the numbers given above show a tendency to replace the three last terms by $4\text{C}_2\text{H}_4 + 5\text{C}$.

It has long been known that finely divided combustible powders suspended in air may produce explosions. This was pointed out in 1878, when an explosion in a flour mill in Minneapolis caused the explosion of another 25 feet distant, and this of a third at the same distance. (Report of Chief Engineer W. M. Brackett.) The cause of these explosions has been studied by Prof. S. F. Peckham, *American Journal Science*, XVI, 301.

The explosion in the Seaham colliery in September, 1880, drew attention anew to this subject, and Prof. Abel undertook the investigation of the question. For a notice of his report to the Home Secretary, see *The Engineer*, July 29, 1881; *Chemical News* 44, 16, 27, 39; or *American Chemical Journal*, 3, 298.

Abel used various powders in these experiments, and one of the most curious results obtained was that the most sensitive of the Seaham powders contained the least proportion of carbon, and more than one-half of its material was incombustible. The special experiments which were suggested by this observation showed that powders which are entirely incombustible, and are not susceptible of any chemical change through the action of flame, become very dangerous when brought in contact with a mixture of fire-damp and air. This effect seems to be attributable, at least in part, to the fact that the particles in passing through a flame become incandescent, so as to localize and increase the heat. One of the powders formed an explosive mixture in air containing only 2 per cent. of gas, and when a current of air was blowing with a velocity of only 5 decimetres per second, one and a half per cent. of gas was sufficient to make the mixture explosive. The coal dusts in mines not only develop and extend explosions, through their rapid inflammability and their disposition to remain suspended in currents of air, but they may also intervene as a means of propagating a flame rapidly as far as they extend, and rendering a proportion of fire-damp explosive which would not otherwise be dangerous.

A description of an explosion in a Nova Scotia coal mine, due to dust, is given in *American Journal of Science* [3] XXII, 18, and the subject of the explosions is discussed in the *Transactions of the North of England Institute of Mining and Mechanical Engineers*, XXXI, 127 and 145. *The Engineer* of September 14, 1881, gives an account of an explosion in a corn mill, and states that rice mills are still more dangerous. *The Engineer* of March 3, 1882, states that of 84 serious fires in mills since 1876, the origin of 56 was unknown.

In my lecture in these Proceedings on the Causes of Explosion, I have called attention to the work of Abel and of Champion and Pellet on the subject of communicated vibrations. Some fresh and interesting illustrations of the communication of sound vibrations to masses of matter can be found in a paper on Mill Floors, by C. J. H. Wood-

bury, in the *Transactions American Society of Mechanical Engineers*, 1882.

A. Girard gives an account of the preparation of hydrocellulose and its derivatives in the *Annales de Chimie et Physique* [5], 24, 337-384, and a note on the subject is found in the *Journal of the Chemical Society*, CCXXXIII, p. 378. Celluloid substances often undergo a remarkable modification in their physical state. Their flexibility and natural elasticity disappear, and they become brittle and easily reducible to powder. By the action of mineral and even vegetable acids, cellulose, $C_{12}H_{10}O_{10}$, before becoming saccharified, is transformed by hydration into a new compound, $C_{12}H_{11}O_{11}$, which the author terms hydrocellulose. It closely resembles cellulose, but differs from it by its extreme brittleness.

The methods of preparation may be divided into three general classes: 1. The immersion of the celluloid material in a powerful and concentrated acid. 2. The exposure of the material to acid vapors. 3. Methods dependent on the employment of weak acid solutions requiring a more or less prolonged contact, or a temperature above the normal one. The ultimate product is the same by either method whether cotton, flax, hemp, jute, paper, wood or elder pith is used.

Only the mineral acids have the power of transforming cellulose into hydrocellulose by simple immersion. The reaction proceeds most easily with sulphuric acid; it is less energetic with phosphoric acid. If sulphuric acid is employed its strength should be carefully determined, and the most convenient for use is of sp. gr. 1.453. The fibre is immersed in it at 15° and allowed to remain 12 hours. Hydrochloric acid, when used at 21° B, transforms the fibre into hydrocellulose in 24 hours. Hydriodic, hydrobromic and hydrofluoric acids behave in a similar manner in aqueous solutions. When nitric acid at 43° B. is employed, the product consists of a mixture of hydrocellulose and nitrocellulose: weaker acid fails to yield any considerable quantity of hydrocellulose. When cellulose is immersed in syrupy phosphoric acid it is only very slightly modified.

Cold, moist hydrochloric acid gas transforms cellulose into hydrocellulose in about an hour. When employed warm and moist, the reaction is complete in a few minutes. Girard states that the action of hydrochloric acid on cellulose has afforded him the means of establishing with certainty the nature of the phenomena resulting in the production of hydrocellulose. Hydrobromic and hydriodic acid resemble hydrochloric in their behavior.

Dilute solutions of sulphuric, hydrochloric, nitric and phosphoric acids (1 in 100 for example) when used to saturate cellulose, effect the transformation into hydrocellulose in from two to three months, if after immersion the fibre is left in the air at the ordinary temperature. The action is complete in one month when a 3 or 4 per cent. solution is employed. If, however, the solution is heated to 60° – 70° a few hours is sufficient. A one per cent. solution of the acid, at the above temperature, renders the cellulose completely friable in a few hours. When the cellulose is immersed in a five per cent. solution of oxalic acid, dried in air and heated in closed vessels to 100° , the change is complete. When tartaric, citric, acetic and formic acids are used it is incomplete.

When the celluloid material, such as a fibre of cotton, is immersed in a strong solution of potash, it becomes swollen or "mercerised." It then possesses the property of becoming blue with iodine, like that treated with sulphuric acid. No hydrocellulose is formed, however, though the swollen fibre presents the same appearance under the microscope as that acted on by sulphuric acid.

Hydrocellulose, however it may be prepared, has always the same composition. It is a fine white powder, which oxidizes rapidly on application of heat or prolonged exposure to the air. Samples for analysis were always dried by the author in a vacuum, or in a current of some inert gas. It is to be regarded as a carbohydrate intermediate between cellulose and glucose. Its production is always accompanied by that of glucose, and in no case could Girard obtain the theoretical yield of hydrocellulose. Its production from cellulose is due to direct hydration, the necessity for the presence of water in the operation being direct proof thereof. Girard shows that the theory that the modification of celluloid substances by direct dehydration and carbonization is due to the dehydrating power of certain salts, ought not to be admitted, since it is to the direct action of acids liberated from these salts when in contact with vegetable matter that the phenomenon is due. It is only at relatively high temperatures and by a secondary action that carbonization takes place.

Hydrocellulose is characterized by its great friability. It differs from cellulose in the greater sensibility which it exhibits towards all reagents. It can best be distinguished from cellulose by the facility with which it is oxidized. When heated in sealed tubes at 180° with sulphuric acid (5 per cent.), cellulose dissolves completely in 8 to 10 hours, yielding a solution which is almost colorless, and evolving no

gas. Hydrocellulose also dissolves under the same circumstances, but leaves an abundant deposit of carbon, and on opening the tube there is a copious disengagement of gaseous products. Heated in sealed tubes with seven or eight times its weight of acetic anhydride, hydrocellulose dissolves instantly, as soon as the temperature reaches 180° , whilst two or three hours are required to dissolve cellulose. It is remarkable that dye-stuffs, which can be made to color cellulose only with great difficulty, possess a great affinity for hydrocellulose.

Cellulose and hydrocellulose yield identical nitro-compounds, and hence Girard concludes that the hydrocellulose is dehydrated before it is nitrated. It yields only the same amount of nitro-compound as cellulose. The yield of pyroxylin is greater when the hydrocellulose is not used in the form of powder.

Girard points out that the rotting of window-curtains in towns is probably due to the production of hydrocellulose by the action of hydrogen sulphide and sulphurous anhydride in the air. He also attributes the dry-rotting of wood to the production of the same substance by the action of acids generated by the fermentation of saccharine matter.

As nitric acid is extensively used in the manufacture of the high explosives, the dangers attending its transportation and storage should be pointed out. Owing to the burning of a car containing nitric acid at Baden, Prof. R. Haas of Carlsruhe made some experiments for the government, which proved that strong nitric acid may cause spontaneous combustion when it comes in contact with straw, paper, tow, and the like, in a confined space.—*The Engineer*, Dec. 9, 1881.

Van Nostrand's Magazine for April, 1882, gives a notice of a new magneto-electric exploder invented by Marcel Deprez.

Giornale d'Artiglieria é Genio (official), No. 2, p. 8, 1882, contains an illustrated article entitled "Instructions on the method of using gum dynamite for the destruction of shells which have failed to explode in firing."

In the *Mitt. u. Gegenstände d. Artillerie u. Genie-Wesens*, Part 7, 1881, Capt. Philip Hess gives the results of an elaborate series of experiments on the best material for the construction of magazines and laboratories for explosives. He abandons altogether the idea that

such buildings should be made very strong with thick walls, since an explosion cannot be confined, and as the falling fragments are a source of danger, the heavier they are the more harm will be done. The lightest material of which they can be made is wood, but this is inflammable, and the flying brands would be dangerous. For this reason sheet-metal has been used, but this is almost as dangerous as stone, and is also quite expensive, while in hot weather it becomes itself a source of danger in dynamite factories. A very safe roofing of asphalt has been used, but it deteriorates rapidly unless protected by sand, gravel or cement, and these are only suitable for horizontal or slightly inclined surfaces. Asbestos pasteboard is an excellent material, being unflammable, weather-proof, a bad conductor and good absorbent of heat, but it is very expensive. Since no suitable material was at hand, Capt. Hess instituted experiments upon materials for impregnating wood so as to render it unflammable and impervious to the weather. Slabs of soft wood were coated with the material to be tested, submerged in water for fifteen minutes, rubbed with the hand, heated in a copper cylinder to a clear red glow, and then cooled. Its inflammability was tested by means of a jet blow-pipe. The best result was obtained by coating the wood with water-glass mixed with such substances as would form insoluble silicates on the surface. Compositions formed with lime or oxychloride of zinc proved excellent, but Portland cement brushed over water-glass gave even better results. When this last is used in dynamite factories it requires to be whitewashed when it has darkened from exposure. None of these preparations should be used on the interiors of magazines or laboratories, on account of the danger of friction from fallen particles. Capt. Hess thinks this research can be advantageously extended to other materials. To test for the power of resistance to frost, he wets the surface profusely and suddenly volatilizes the water by applying the blow-pipe flame. He finds the disintegrating force fairly corresponds to that of frost.

Engineering, of November 4, 1881, describes a hydraulic machine for making prismatic powder just constructed for the Waltham Abbey Factory. As the best pebble powder was found too variable in density, experiments were made in pressing prismatic powder with temporary presses, and excellent results were obtained with a grain two and three-eighths inches across, two inches deep and three-eighths inch hole. The new press can make thirty of these prisms

at each stroke, and the operations of filling, pressing and ejecting are performed in two and one-half minutes. The machine comes fully up to the favorable anticipations formed of it, and it is turning out twenty-five to thirty barrels per day of these large prisms of quite uniform density. The article is accompanied by a cut, which is necessary to a full description.

An illustrated report on the fatal explosion of gunpowder at the factory of Messrs. Wakefield, near Kendal, in July last, by Major Ford, R. A., states that this explosion, as well as two others in press-houses which have occurred since the Explosives Act has been in force, was brought about, not in the operation of pressing itself, but in processes incidental thereto. Press-boxes, which are liable to be the source of danger if friction arises in the press, seem quite unnecessary, and their use has been abandoned in four powder factories of the United Kingdom with satisfactory results. The men were able to spread the mill-cake more quickly and equally on the press-plates, and the plates were subsequently more easily separated.—*The Engineer*, October 7, 1881.

M. Dapremont sends to the *Comptes Rendus*, XCIII, 354, a note on the use of a new chlorate of potash powder.

The *Comptes Rendus*, February 6, 1882, in announcing the award of a prize of 3000 frs. to Lieutenant Colonel Sebert, of the Marine Artillery, reviews at length his work upon explosives and artillery, and refers to the various instruments of precision used in or invented for his experiments.

The Engineer, of September 9, 1881, devotes a leader to the loss of the Doterel, in which it states that the court-martial acquitted Commander Evans of all blame, and found the cause of the explosion in the ignition of coal-gas in a bunker, which, on explosion, exploded the magazine. Exception is taken to the explanation of the court as to the manner in which the explosive impulse was communicated to the magazine. Returning to the subject on January 20, 1881, after the loss of the Doterel, it says, "The news of the explosion on board the Triumph, off Coquimbo, has revived the doubts as to the general management of the Navy which the loss of the Doterel and the subsequent official inquiry had given rise to. We do not remember whether the drier which boasts of the barbarous name of '*xerotine*'

siccative, which means 'drier' twice over in Greek and in Latin, and to which the recent explosion is due, was mentioned in connection with the accident at Puntas Arenas. But in any case there appears to be little doubt the authorities saw cause for suspicion, and the drier, which had already been analyzed and pronounced harmless, was then analyzed again and pronounced to be of so doubtful a character that its use in the Royal Navy was to cease. Since the recent accident, directions have been forwarded to every station to the effect that it is to be regarded as a dangerous explosive, and should be got out of the way as quickly as possible. As far as concerns the Doterel, it is of course difficult to say that this '*siccative*' was the cause of the accident. But it will be remembered that the evidence showed the existence of dangerous communications with the magazine from various parts of the ship. If the explosion which killed three men and injured half a dozen others on board the Triumph had communicated itself to the magazine, the entire ship would have gone to the bottom. The class of compounds to which the name of '*siccative*' is given are varnishes which are added to oil paints to make them dry quickly. They are prepared by boiling linseed-oil with metallic oxides or salts. Formerly, litharge, minium, umber, and gypsum were employed for the purpose, but more recently the oxides and salts of manganese have come into use. They produce rapidly drying *siccatives*, and when added to zinc-white, do not introduce any substance that can be blackened by sulphuretted hydrogen. A mixture of equal parts of manganous sulphate and acetate with an equal quantity of zinc sulphate and ninety-seven parts of zinc-white, added in the proportion of one-half to one per cent. to the zinc oxide with which the oil color is to be prepared, is said to effect the drying of the paint in twelve hours. A similar mixture is the *siccative zumatique de Barruel*, which, according to Bolley, is made by mixing from five to six parts of borous manganate (?) with ninety-five parts of zinc-white, and adding to zinc-white colors in the proportion of about two and one-half per cent. Acetates and manganates closely associated with boiled oils do not form the most stable compounds imaginable. It now appears, from a letter which has been forwarded to the Admiralty by the commander-in-chief at Portsmouth, and written by three survivors of the Doterel explosion, including the carpenter, that they attribute the disaster in the Straits of Magellan to the ignition of xerotine-siccative, and not to the explosion of gases generated in the coal-bunkers, as had been found by the court-martial upon the evidence of Professor Abel. The explosion on board the Triumph, they

state, directed their attention for the first time to the fact that xerotine siccative had explosive properties, and reminded them that within a very short time of the explosion, perhaps fifteen minutes, a leakage of xerotine siccative had been discovered in the paint store-room, which is immediately adjacent to the fore magazine, in which all powder stores, excepting small-arm ammunition, were placed. The presumption is that the escaped composition flowed under the wooden flat of the magazine, and that the inflammable vapor it gave off was ignited by the light carried by the man told off to clean the store-room floor. What remained of xerotine siccative in the cask had been in the meantime thrown overboard by the seamen who are still alive."

A New York chemical firm says that siccative is the trade-name of a concentrated drier to put in paint. It comes in two forms, dry and liquid. When dry it may be sugar of lead, borate of manganese, any of the grades of umber, or a variety of other substances. In the liquid shape it is simply the same substances with some liquid added to carry it. This liquid is generally alcohol, turpentine, or benzine. Benzine is the cheapest and most commonly used.

Under the somewhat misleading title of "Modern Explosives," Mr. B. V. Abbott calls attention to the many accidents caused by explosives, and shows the necessity for more stringent laws concerning their manufacture, transportation, storage, and use.—*Popular Science Monthly*, XX, 794.

The recent edition of the *Encyclopædia Britannica* devotes considerable space to the subjects of "Explosives" and "Gunpowder," by Major W. H. Wardell, of Waltham Abbey, and to "Gun Cotton," by Prof. Abel.

The best recent examples of the text-book, the hand-book, and the manual of explosives are to be found respectively in "Poudres de Guerre" of the "Ecole d'Application de l'Artillerie et du Génie," Böckmann's "Explosiven Stoffe," and Désortiaux' "Traité sur la Poudre et les Corps Explosifs." The first is simple in style, accurate in statement, well digested, and suitably arranged for study. The second forms one of the volumes of Hartleben's *Chemisch-technische Bibliothek*. It rapidly reviews the whole subject and briefly summarizes the results of recent experiments, while it contains a large number

of references to the original papers, and thus serves as a useful index to recent literature. The "Traité sur la Poudre" is a translation, in two volumes, from the German of Upmann and Meyer, but it is greatly augmented. It is published by Dunod.

Gauthier-Villars announce a new serial, under the name "Memorial des Poudres et Salpêtres," which is to be published by the French government. It will appear in two numbers, of from two hundred to four hundred pages each, yearly, at five francs per year. Only officers of the army and navy and government engineers are permitted to subscribe. Each volume will be divided into three parts, containing, 1st. Technical documents; 2d, Administrative documents; 3d, Bulletins of experiments and bibliography.

NAVAL INSTITUTE, ANNAPOLIS, MD.

DECEMBER, 1882.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

PROF. CHARLES E. MUNROE, U. S. N. A.

No. II.

Under the title "Study of the Explosive Properties of Fulminate of Mercury," Berthelot and Vieille give an account of their experiments in *Annales de Chimie et de Physique*, XXI [5], 564. Whether from a theoretical point of view or as regards its applications, the study of this substance is of great importance, since it is the most perfect type of a detonator, and is used in the fabrication of fuses and for the detonation of gun-cotton and nitro-glycerine. Owing, however, to the danger in handling it, and also to the fact that theoretical questions concerning the higher explosives have not attracted attention until of late, this substance has not previously been closely studied. The fulminate examined was extracted from the regulation caps of the Engineers, each of which held about 1.5 grams, and were made at l'Ecole d'Arras. Analysis gave

	Found.		Theory ($C_4N_2Hg_2O_4$).
† Hg . . .	71.30	Hg . . .	70.40
‡ CO . . .	19.40	CO . . .	19.75
‡ N . . .	9.60	N . . .	9.85
§ H . . .	0.04		
	<hr/> 100.34		<hr/> 100.00

* As it is proposed to continue these notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications, trade circulars, or expert testimony in infringement cases.

† Precipitated as sulphide after solution in HCl with addition of a little $KClO_3$.

‡ Determined by volume after explosion in a closed vessel.

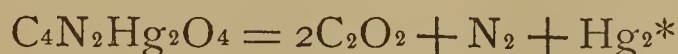
§ Found in the same way, but is probably accidental, and came from the grease used for lubricating the joints of the vessel.

The slight excess of metallic mercury shown in the analysis came from free metal mechanically mixed with the fulminate.

Three grams of the fulminate enclosed in a tin-foil cartridge were suspended in the centre of a steel cylinder and exploded by an electric current. The cylinder was first filled with pure nitrogen whose temperature and pressure were accurately known. Five experiments gave as a mean 234.2 cc. of gas for 1 gram of fulminate. Theory requires 235.8 cc. This gas contained in 100 volumes—

HCN + CO ₂	.	.	.	0.15	} Ratio 2.04.
CO	.	.	.	65.70	
N	.	.	.	32.28	
H	.	.	.	1.87 (accidentally present).	

This proves that mercury fulminate in decomposing follows the very simple reaction



one equivalent (284 grams) furnishing 66.7 litres of the gas (at 0° and 76 cm). From this it is seen that the detonation of mercury fulminate does not give rise to the formation of any substance capable of undergoing a notable † dissociation under the conditions of the experiment, consequently no gradual recombination can take place during the cooling which would retard the expansion of the gas and diminish the violence of the initial blow. This explains the brusqueness of the explosion. It would still be more brusque but for the condensation of the mercury vapor. In all cases the nature of the product explains the character of the explosive blow.

During these last experiments the steel cylinder was immersed in water in a calorimeter and the heat of formation determined. They thus found for one equivalent (284 grams) + 116 cal. for a constant volume, and + 114.5 cal. for constant pressure. This quantity of heat would be sufficient to raise the temperature to 4200°.

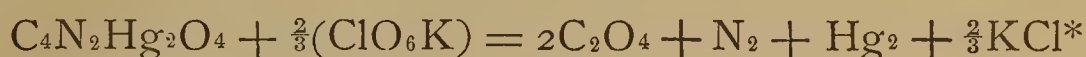
The heat of formation of mercury fulminate may be calculated from its constituents, and is found to be -62.9. The heat disengaged in the decomposition of the fulminate then results both from the separation of its elements and the simultaneous combustion of the carbon in the oxygen. This is the result obtained in a closed

* $\text{C}_2\text{N}_2\text{HgO}_2 = 2\text{CO} + \text{N}_2 + \text{Hg}$.

† They neglect here the traces of dissociation of the carbon protoxide which, as shown by Deville, manifests itself at a red heat by forming scarcely perceptible quantities of carbon and carbon dioxide.

vessel in an atmosphere of nitrogen. In contact with air, however, carbon dioxide is formed owing to the total or partial combustion of the carbon protoxide, and this disengages $+136.4$ cal., making in all $+250.9$ cal. under constant pressure. But this additional quantity of heat does not increase the force of the initial blow, since it results from a subsequent combustion.

The contrary effect takes place when we mix the fulminate with potassium nitrate or chlorate. These also convert the carbon protoxide into dioxide with an evolution, at constant pressure, of $+258.2$ cal. with the chlorate after the reaction,



and of $+229.4$ cal. with the nitrate,

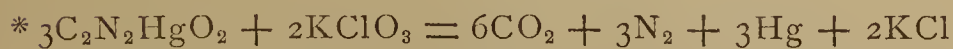


The evolution of heat is then double that produced by the pure fulminate; but the initial blow is tempered here by the phenomena of dissociation due to the carbon dioxide which renders these explosive mixtures less brusque in their effects. The temperature developed is reduced at the outset by the distribution of the heat among the more considerable mass of products.

The density of the fulminate was found to equal 4.42, being calculated from the measured pressure.

The tension developed in a closed vessel was determined in the *éprouvette*, which was used by Sarrau & Vieille in their researches on gun-cotton, and was measured by Noble *crusher* gauges. The apparatus is described at length, but the illustrations given are essential to clearness. In comparing the results obtained from introducing varying weights of the explosive in the same vessel, the ratio of the weights of the explosive to interior volume of the *éprouvette* is called the *density of the charge*.

Density of charge.	Weight of fulminate.	Pressure in kilos per square centimeter.
0.1	2.43	477
0.2	4.86	1730
0.3	7.39	2697
0.4	9.72	4272 †



† Calculations from Marriotte's law, supposed applicable under these circumstances, show a pressure of at least 2070 atmospheres.

In the last experiment the lower piston was broken in three pieces, and the copper obturator was driven, in the form of fine threads, into the annular space of $\frac{1}{100}$ millimeter existing between the piston and the concentric canal. These phenomena are characteristic of the brusqueness due to decomposition through detonation.

However, if the local action with fulminate is greater than with ordinary explosives, we cannot conclude that the mean pressure developed under a given *density of charge* is also greater. It is far from it, for Sarrau & Vieille found for gun-cotton under precisely similar conditions,

Density of charge.	Pressure in kilos per square centimeter.
0.1	1085
0.2	3120
0.3	5575
0.4	8745

This statement of these relations is otherwise in accordance with those given concerning the quantity of heat and the volume of gas produced by the two explosives. These are, in general, that it is neither the volume of gas disengaged nor the quantity of heat produced which impresses on the fulminate its peculiar character and specific advantages, for it is surpassed in both these directions by many explosive bodies. The pressure under a given *density of charge* is less also for fulminate of mercury than for gun-cotton, and nearly the same as for dynamite of 75 per cent., which is less than pure nitro-glycerine.

The superiority of the power of fulminate is manifested best when in contact with a body, and it is due to three causes: the nearly instantaneous decomposition of the body by simple inflammation; the almost total absence of dissociation products, and finally the great density of the explosive. By reason of these conditions, the definite products of the reaction appear to form all at once, before the matter has had time to take a volume notably superior to that of the primitive solid. If, then, the fulminate detonates in a receptacle, in contact with the sides of the same, it develops on it, at the start, an instantaneous pressure which bears no definite relation to the mean pressure controlled by the capacity of the receptacle. Berthelot and Vieille have sought to estimate the pressure developed under these conditions of contact, and they find that the curve for the explosive substances, representing the tension in a closed vessel, tends rapidly toward an

asymptote. Admitting this, mercury fulminate with an absolute density of 4.42 will develop in contact a pressure of 48,000 atmospheres, whilst compressed gun-cotton, with a density of 1.1, such as employed for military purposes, will develop in contact only 24,000 atmospheres. Calculation will show that no other explosive known will give in contact an instantaneous pressure at all comparable to that of the fulminate. Without insisting too strongly on these numbers, it appears useful to notice them, since they mark the general relations of these phenomena. The superiority of the effects due to the explosive shock of the fulminate is explained by this circumstance joined with the absence of dissociation; nothing can resist direct contact with this explosive.

In one experiment the fulminate was deposited on the bottom of the steel calorimeter, and the mean pressure, calculated in advance, could not have been more than 50 atmospheres. Yet the steel vessel was bruised all over the surface occupied by the charge, the contours of which were found impressed on the metal.

We know that fulminate of mercury is eminently fitted for determining the nearly instantaneous propagation of deflagration (which is so distinct from inflammation, properly called), and which is indispensable for causing dynamite and compressed gun-cotton to develop their entire power. Berthelot has given elsewhere* a general theory in explanation of these characteristic effects, which refers the violence of the initial blow to the brusqueness of the successive decompositions, and also to the enormous pressure exerted at the point of contact during the course of these decompositions. These results sustain his theory and show why the fulminate of mercury is particularly adapted to provoke true detonations in other explosive bodies.

Nitric peroxide, which plays so important a part in the high explosives, exhibits such anomalies in its volume composition and vapor density as to make the study of its properties of great importance and interest, and the paper of Berthelot and Ogier in *Comptes Rendus*, XCIV, 916, on "The Specific Heat of Hyponitric Gas" is of especial value. Like acetic acid and analogous bodies the density of the vapors varies very greatly with the temperature, departing from the laws of Marriotte and Gay-Lussac. This makes the determination of the specific heat very tedious and difficult. However, they have determined the loss of heat between 200° and 26° and between 100° and

* Sur la force de la poudre, 2d edit. 1872, 165.

26°, and they have deduced for the mean specific heat of a molecule (referred to a weight of 46 grams) between 100° and 200° a number (+ 17.4) greater than the sum of the specific heats of its constituents, oxygen and nitrogen, and that the gas followed the same ratio as condensation 3:2 as carbonic acid, protoxide of nitrogen and the like. Between 100° and 26°, however, the specific heat is greater than between 200° and 100°. This is explained in saying that the heat disengaged between 100° and 26° represents the sum of two effects: the one corresponding to the heat lost without a change of molecular state, which may be estimated to approach somewhat the specific heat between 100° and 200°; and the other corresponding to this change of state, which is + 3 cal. 980, which is nearly equal to the heat of vaporization of the same (+ 4 cal. 300 at 76 cm). The true heat of vaporization, that is to say the heat used in the work of bringing the hyponitric gas to its theoretical density, should be defined as the sum of the heat of liquefaction and of a quantity imparted to it through all this interval. The optical properties of hyponitric gas and the progressive variation of its density accord in their general significance with the thermal phenomena indicated in this paper.

A trial has been going on for some time in the United States Circuit Court of the Southern District of New York, in which the Atlantic Giant Powder Company have sought to prove that the Dittmar Powder Manufacturing Company were infringing their rights by manufacturing and selling an explosive called Glukodine. A suit* had already been brought against the California Vigorite Powder Company, to stop the manufacture of vigorite, which had the composition of

Chlorate of Potash	. . .	17.50 per cent.
Nitrate of Potash	. . .	18.75
Chalk	. . . . .	8.75
Sawdust	. . . . .	11.25
Nitro-glycerine	. . . . .	43.75

and it was claimed by the plaintiffs that glukodine was a substance of similar nature, differing only in certain unessential particulars, and being practically a nitro-glycerine dynamite; while the defense held that it was an entirely new substance, in which the nitro-glycerine and nitro-saccharose, or the elements of each, were either united chemically or chemico-physically. In the attempt to sustain these oppo-

* This suit was dismissed by Justice Field.

site views a great mass of evidence has been taken, from which we abstract the following statement of facts observed and experiments made. Mr. Carl Dittmar describes the process for making glukodine as follows :

“I take saccharose (cane sugar) and dissolve this in anhydrous glycerine to the extent of the latter's dissolving capacity, which will vary both with the quality of the sugar and the quality of the glycerine used in the solution. The solution I then subject to the chemical reaction of a bath of the mixed acids (nitric and sulphuric acids) in their concentrated form. In the event of the formation of lumps or solidification, I add such a quantity of free solid sugar as will suffice to remove such lumps, and when these have been removed and the nitration is complete the usual alkaline solutions are applied, and they will completely neutralize the product, which is glukodine.”

Glukodine is a whitish liquid fluid after the addition of free sugar, the sugar dissolving in it, and soluble in ether in all proportions. Nitro-cellulose absorbs about four times its weight of glukodine, and for the preparation of white and black glukodine this solid powder is mixed with 10–15 per cent. of free sugar, with carbonate of soda, with nitrate of soda or potash, and with wood-fibre or charcoal. The kind and amount of the various ingredients vary with the price and quality desired.

Prof. P. De P. Ricketts finds by analysis that white glukodine powder contains

Matter soluble in ether (glukodine),	.	36.40 per cent.
Free sugar,	. . . . .	8.40
Soda salts (mostly nitrate),	. . . . .	31.20
Nitro-cellulose,	. . . . .	23.36
		<hr/>
		99.36

And that black glukodine powder contains :

Matter soluble in ether (glukodine),	.	34.24 per cent.
Free sugar,	. . . . .	8.76
Soda salts (mostly nitrate),	. . . . .	37.84
Nitro-cellulose and charcoal,	. . . . .	19.31
		<hr/>
		100.15

Prof. Charles F. Chandler analyzed the same samples with Prof. Ricketts, and reached similar results as to all the ingredients except

the glukodine. He testifies to having found in the white glukodine powder:

Nitro-glycerine, 33.19 } instead of 36.40 per cent. of glukodine.
 Nitro-saccharose, 3.21 }

and for the black glukodine powder:

Nitro-glycerine, 30.23 } in place of 34.24 per cent. of glukodine.
 Nitro-saccharose, 4.03 }

Prof. Ricketts says that nitro-saccharose is a white solid substance produced by the reaction of concentrated nitric and sulphuric acids upon cane-sugar. It is very unstable, and indicates a much greater tendency to decomposition than either nitro-glycerine or nitro-cellulose. Its unstable qualities are extremely pronounced, as it decomposes even when admixed with water and while standing for any considerable time. He placed a jar containing nitro-saccharose and water of ordinary temperature in the laboratory, and after a few days the red fumes indicating decomposition were plainly perceptible. Its affinity for nitryl is slight, as shown by the fact (1) of its inconstancy, and (2) that my analysis of nitro-saccharose at different periods of time gave varying amounts of sugar. I have made no tests as to its explosiveness and as to the conditions under which it will explode, but the theoretical formula of its composition indicates its close relationship to both nitro-glycerine and nitro-cellulose. The three compared together are as follows:

Glycerine.	Saccharose (cane sugar).	Cellulose.
$C_3H_8O_3$	$C_{12}H_{22}O_{11}$	$C_6H_{10}O_5$
Nitro-glycerine.	Nitro-saccharose.	Nitro-cellulose.
$C_3H_5(NO_2)_3O_3$	$C_{12}H_{18}(NO_2)_4O_{11}$	$C_6H_7(NO_2)_3O_5$

Nitro-saccharose, however, according to the analyses of the prepared samples hereinbefore referred to, would have the formula $C_{12}H_3(NO_2)_{19}O_{11}$. This approximate identity of formulæ indicates a close resemblance between the three explosives; this is further borne out by authorities which state that nitro-saccharose has been used as the charge for percussion caps, which would again indicate its sensitiveness to shock and its great detonative qualities.

Carl Dittmar stated that nitro-saccharose is extremely sensitive to atmospheric influences, and detonates at a considerably lower degree of heat than is necessary for the explosion of nitro-glycerine. He has found it to be equally as and more sensitive to percussion or con-

cussion than nitro-glycerine, and as liable as the latter under like conditions to explode by accidental percussion or concussion, when confined in the same way as nitro-glycerine must be confined in order to be susceptible of explosion in that way. Like nitro-glycerine, it decomposes when unconfined, giving up its gases, but without explosion. It is stronger and quicker than nitro-glycerine, bearing a closer resemblance to the ordinary fulminates; in fact, so quick and energetic is its detonation, and so great is its power, and so readily is it decomposable, that for many years it was used as the charge for percussion caps, where quickness, readiness and great force of explosion are necessary requirements. Until now, however, it has been practically useless as a blasting medium, owing to certain of its characteristics which have prevented its manufacture and use upon an economical and commercial scale. As a fulminate it could be made in small quantities, but its sensitiveness to atmospheric influences and hygroscopic qualities soon drove it from the market, almost entirely if not quite so, until to-day it is regarded more in the light of a chemical curiosity than in that of a valuable and available explosive.

The difficulties encountered when manufacturing this explosive in larger quantities than necessary for small fulminating charges were these: It assumed, when undergoing the process of nitration, the consistency of a sticky mass which, when washed with water of ordinary temperature, quickly solidified, and hardened to such an extent that its thorough permeation by the alkaline wash waters and solutions which are designed and necessary to rid the compound of all superfluous and free acids was rendered impracticable, thus preventing them from affecting the entire mass, whereby free and uncombined acids remained present in the compound, greatly impairing its usefulness as an explosive medium. These free acids would, under conditions of the confinement of the compound, which confinement must needs be very close in order to prevent decomposition from the effect of warm or moist atmosphere, and in order to counteract the hygroscopic tendency of the nitro-saccharose, generate sufficient heat by gradual decomposition of the compound to induce spontaneous detonation, or detonation by the superadded heat resulting from an accidental blow or percussion. If unconfined, this gradual decomposition without detonation would wholly destroy or materially diminish the explosive force of the compound.

On the other hand, if washed with tepid and like alkaline solutions, so considerable a portion of the nitro-saccharose would be dissolved

therein and pass off with the wash waters, or so much thereof would be decomposed thereby, and injuriously affected in its explosiveness, that the yield and result would be highly unsatisfactory and unprofitable, while its hygroscopic and decomposable tendencies rendered its close confinement in air and water-tight enclosures absolute requirements.

To determine if glukodine were a mechanical mixture of nitro-glycerine and other substances or not, Mr. Thomas Volney mixed 12 parts of glycerine with 5 parts of well-dried cane sugar, and then nitrated this solution in the same way that glycerine is nitrated for nitro-glycerine.

A weighed quantity of this product was then put into an open glass vessel and placed on a bath of mercury in a cavity made in cement, resting upon the dome of a steam boiler, with steam at about 20 lbs. pressure, and kept there for 24 hours; at the end of that time nothing was left but nitro-sugar; the nitro-glycerine had evaporated. On weighing he found the nitro-sugar to be 20 per cent. of the weight of the mixture originally put into the glass. This experiment was repeated three times: in one of these he covered the glass with wire gauze, and this with cotton, which condensed the nitro-glycerine vapor; this cotton was washed with ether, which was then evaporated and left pure nitro-glycerine.

He finds after dissolving nitro-sugar in nitro-glycerine in a great variety of proportions that the greater the proportion of nitro-sugar the thicker the solution. With 3 parts of nitro-sugar to 2 parts of nitro-glycerine, the consistency is that of strained honey; with 150 per cent. of nitro-sugar we have a viscid, sticky mass like fir balsam. He states that he was unable to dissolve sugar in either nitro-glycerine or glukodine.

Dr. Henry Morton verifies Mr. Volney's experiment in the following statement: "Taking advantage of the circumstance that nitro-glycerine will evaporate readily at temperatures about 125 deg. centigrade (257 deg. Fah.) without danger of explosion, which requires a temperature of about 492 deg. Fah., I took 30 grains of glukodine (made by nitrating a mixture of 12 parts glycerine and 5 parts sugar), and placed it on a mercury bath whose temperature I maintained carefully at 120 deg. to 130 deg. C. for six hours.

"Over the vessel containing the glukodine I placed a sheet of wire cloth, and this I covered with cotton wool.

"In six hours the nitro-glycerine had all evaporated from the nitro-

sugar, which was left as a transparent gum, weighing 5.55 grs., or $18\frac{1}{2}$ per cent. of the original quantity taken. A large part of the nitro-glycerine was condensed in the cotton-wool, from which it was readily dissolved out with ether, and this being removed by evaporation, left the nitro-glycerine with all its well-known physical properties and its peculiarly violent detonating quality when struck or suddenly heated to a temperature of about 490° F."

Arthur H. Elliot, F. C. S., has studied nitro-saccharose and records his results in the *Jour. American Chem. Soc.* 4, 8, 147, Aug. 1882. He tried several methods of manufacture and recommends the following: Pure crystals of cane-sugar were reduced to a powder fine enough to pass through a 100-mesh sieve, and then dried in a water bath. 800 grams of H_2SO_4 (sp. gr. 1.84) were mixed with 300 grams of HNO_3 (sp. gr. 1.53). 95 grams of sugar were used, and one-half of it was slowly stirred into the acid mixture, and the whole allowed to cool. Then the rest of the sugar was added, and the completed mixture allowed to stand one hour, with frequent stirring. The acids were now poured off the nitro-saccharose, and the latter, when washed and kneaded thoroughly with water, weighed 135 grams. When the mass was first removed from the acid mixture it had the consistence of soft butter, but as the washing and squeezing progressed it became more and more resinous and white. A further kneading in water as hot as the hand would bear, using two lots of one litre each, and finally in water containing one per cent. of potassic carbonate, reduced the well-squeezed mass to 109 grams. This method appears to give the best results in the matter of washing, but the material slowly decomposes, the water in which it is kept becomes acid and smells faintly of hydrocyanic acid. Nevertheless the nitro-saccharose made by either of the methods used changes so slowly that he kept it under water for over a year without any great change in appearance or bulk, beyond the acid reaction mentioned above.

He tested its solubility in many different solvents, and its action toward ferrous chloride and ammonium sulphhydrate, and analyzed it, and he finds (in 4, 9, 186, Sept. 1882) that his results may be represented by the formula $\text{C}_{12}\text{H}_{14}(\text{O}.\text{NO}_2)_8\text{O}_3$ and that the substance is an octonitrate.

A new explosive has been invented by M. Petri, a Viennese engineer. The name given to it is *dynamogen*, and, according to the *Neue*

Militärische Blätter, it is likely to compete seriously with gunpowder. The inventor states that it contains neither sulphuric acid, nitric acid nor nitro-glycerine. The charge of dynamogen is in the form of a solid cylinder, which can be increased in quantity without being increased in size, by compression. The rebound of the guns with which the new explosive has been tried is said to have been very slight. It is also said that the manufacture of dynamogen is simple and without danger, that it preserves its qualities in the coldest or hottest weather, and that it can be made at 40 per cent. less cost than gunpowder. [*The Engineer*, June 2, '82]. In an article on Experiments made by the Austrian Artillery in 1880, the *Revue d'Artillerie* (XIX, 3, 242) says they have made experiments on the relative explosive force of powder and of a new explosive called *dynamogène*, proposed by Messrs. J. F. Petry and Louis Princeps. This substance is made by the aid of a prepared paper, the fabrication of which is kept secret. For firing they roll it up like a band of paper and place it in a cartridge-case. When they fired these cartridges they gave less smoke and heated the gun less quickly than powder, and also after long firing left only a slight residue, which was easily removed. Unfortunately the *brisant* effect of this compound on the gun is very considerable, and besides the accuracy of fire is much inferior to that of powder.

Two years ago, Hellhoff, of Berlin, patented a process for making explosives from crude coal-tar oils by direct nitration with strong nitric acid. The mixture of various nitro-substances thus obtained was washed and dried, then mixed with oxygenated substances. The alkaline nitrates, chlorate of potash, and the strongest nitric acid served for this purpose. Experience gained by long-continued manufacture with the aid of steam proved that the separate fractions of the crude tar oils, even those of the highest boiling point, were capable of nitration and gave a satisfactory yield of nitro-derivatives.

The question naturally arose whether the tar itself could not be nitrated and utilized for making explosives. Experiments made in this direction soon showed that the treatment of coal-tar with strong nitric acid was a very dangerous operation, that its employment on a large scale would be attended with great difficulties, and the greater part seemed to be burned up and lost. In subsequent experiments, therefore, an acid of 1.53 to 1.45 specific gravity was employed. The liquid tar is gradually stirred into the acid, the surface of the acid

becoming covered with it. After a while this layer of tar contracts on stirring and settles slowly to the bottom. In about ten minutes the mass at the bottom puffs up, and gradually changes from a liquid to a solid or pasty state. The completion of the operation can be recognized by the mass rising from the bottom and spreading itself evenly over the surface. When the acid has been all used up, the tar which is added no longer contracts and settles to the bottom. The chemical changes do not produce an excessive amount of heat, so that cooling is unnecessary.

The product thus obtained is well washed with excess of water, and the sour wash-water that remains in its pores is expressed out. The purified product is then mixed with the oxygenated bodies above-mentioned. One part by weight of the product dissolves very slowly, with the evolution of but little heat, in three parts of nitric acid, specific gravity 1.52. All these substances gave new explosive compounds of different degrees of violence. The power possessed by a solution of these new nitro-derivatives in concentrated nitric acid is shown by the fact that a small quantity of it, when exploded by a double dynamite exploder, was able to shatter an iron shell.

Owing to the varying composition of the tar it is impossible to give the exact proportions in all cases of the oxygenated substances which must be added, but in the experiments it was found that two to five parts of concentrated nitric acid, chloric acid, or four to six parts of salts, were sufficient for one part of the nitro-derivative. The great advantages offered by this process are cheapness of the material to be acted upon, the cheapness of the lighter acid used (the difference is about 60 per cent.), and finally in the quiet and regular manner in which the operation takes place, permitting of the use of more simple and less expensive apparatus, etc.

These favorable results led to further experiments upon pitch, the paraffines, etc., as well as the mineral oils. The possibility of nitrating the latter seemed probable from their great similarity to the crude tar oils. Experiment, in fact, proved that they reacted exactly alike. But the strongest nitrating agents are required to act upon the purified mineral oils used for illumination. A mixture of equal weight of the strongest nitric and sulphuric acids, or a mixture of an alkaline nitrate with sulphuric acid, was employed.

On paraffines and similar products the weaker acids are as ineffective as on purified oils. By the action of the nitrating agents mentioned upon purified mineral oils, nitro-compounds were precipitated,

of a light yellow or light brown color, having the external appearance of rancid fat. These products are difficultly soluble even in the strongest nitric acid. Pitch treated with nitric acid of 1.45 to 1.52 specific gravity gave a yellow-brown solution, and from this light yellow to brown scales separated on washing with water. The oil and pitch from wood-tar were treated with the weaker acid (1.45), and those from brown coal and stone-coal with the stronger acid (1.52). The products thus obtained are easily soluble in strong nitric acid with slight evolution of heat. These nitro-compounds when mixed with oxygenated bodies also form powerful explosives, but the quantity of the latter used must be two to four times greater than that added to nitro-derivatives of tar. There is no special advantage in working these materials as compared with tar or even the tar oils, for a high grade of acid must be used, while the increased quantity of oxygenated salts raises the price still higher. Still, this process is of some importance in so far as pitch is concerned, since the price of tar is likely to increase as more uses are found for it.

All the special products of the distillation of coal having been found capable of being converted into explosives by nitration, it only remained to try an experiment on the original materials, coal and peat. Wood was excluded from the list, for its conversion into an explosive (pyroxyline) had already been accomplished by Trauzl. It was found that the direct conversion of coal into an explosive by extracting the nitro-products would involve very expensive and tedious manipulations. After numerous unsuccessful experiments in which the product was either completely burned up or the coal was but slightly acted on, we were induced to try a gradual nitration. The coal, in form of a fine dust, was first treated with weak nitric acid, specific gravity 1.40 to 1.48; the weight of acid required was ten times that of the coal used. When stone-coal was introduced slowly into the acid the rise in temperature was inconsiderable, and some hyponitric acid was formed. The action was much more violent in the case of brown coal, and least so with wood-coal. After the operation with any coal, a large portion of the material to be nitrated remained apparently unaffected and formed a thick sediment on the bottom of the vessel, while the nitro-product was dissolved in the acid layer above and imparted to it a light brown color—with brown coal nearly a tar color. When this fluid layer was well washed with water the nitro-product was thrown down as a fine brown powder. This precipitate was filtered out and washed repeatedly until the wash

great profits, rival companies have been organized and will soon enter into a competition which will probably result in a fall of prices. The advantages of the site on the Ayrshire coast are cheapness of the land, freedom for manufacture with a minimum of danger within, and no valuable property without, the factory; direct linking with railway system of the country; good facilities for loading sea-going vessels direct from the magazine; ports in the vicinity where vessels may lie until wanted.

The nitric acid for the manufacture of the nitro-glycerine is made on the premises; the sulphuric acid, the fuses, and the detonators are made at the factory at Westquarter, Stirlingshire. Formerly sulphuric acid was transported in glass carboys, which were both bulky and fragile, but now it is brought in large, long, flattened iron tanks, it having been found that iron of moderate thickness will resist the action of sulphuric acid for a long time. This has resulted in considerable economy in the cost of conveyance. The converting houses are placed on elevations and the acids and glycerine are brought up a tramway, while the nitro-glycerine flows down to the kieselguhr kneading houses through leaden troughs. The process of manufacture of the nitro-glycerine is too vaguely described to bear repeating, but the product is spoken of as a "muddy, yellowish fluid." All the nitro-glycerine produced is made into dynamite upon the day of its manufacture. The nitro-glycerine and kieselguhr are mixed by hand. The cartridges are filled by women. This is accomplished by the use of a four-sided hopper, fixed to the side of the building, and terminating downward in a sloping point, to which a small brass tube is affixed. The size of this tube regulates the size of the cartridge. Loose dynamite from the box beside the worker is spooned into the hopper as occasion requires. With the left hand the worker seizes a water-tight cartridge paper, and wraps it round the brass nozzle. With the right hand she rapidly moves a lever up and down, which presses the dynamite into the cylinder and cartridge. The cartridges are packed in water-tight paper and put in boxes containing fifty pounds each. The buildings in which the filling is done are built in accordance with the Explosives Act, and the maximum number of persons and amount of dynamite allowed in each is fixed by the government inspector. Great care is manifested in all the operations, and the works are carefully policed, so that in the ten years of operation no workman has lost his life through a casualty at the works.

The total quantity of dynamite produced each day is from four to six tons, and the selling price for years has been £200 per ton. It is sent to all parts of the world except the United States. For the purpose of transportation the company own a couple of steamers and a smack. The steamer Maggie, with a cargo of fifty tons of dynamite and many thousand detonators, successfully weathered a gale on a voyage from the Clyde to London.

“As a rule the quality of dynamite manufactured is very uniform. One may stand by a foot-pound recoil apparatus, which swings a large mortar, and is self-adjusting, and observe a dozen one-quarter ounce cartridges, taken from different parcels on different days, perform precisely the same amount of work, namely, about 900 foot-pounds, or nearly half a ton, lifted one foot high.”

About 300 yards from the dynamite factory the company have erected works for the manufacture of nitro-gelatine, which as yet is not much known as a blasting agent, but which has rending properties fifty per cent. stronger than dynamite. Success is attained in the mixing of the nitro-cellulose and nitro-glycerine, to form the nitro-gelatine, so thorough and so well proportioned that the gelatine leaves no stain on either the hand or on paper. Under these conditions there can be no exudation. At present only about half a ton per day of the new explosive is produced, but arrangements are maturing for the manufacture of a much larger quantity.

It is in bad taste for the writer to accuse the manufacturers of the United States of piracy, while in the same sentence he states that, after long litigation, our courts have declared the Nobel patent virtually invalid.

The method of submarine blasting devised by Major Johann Lauer of the Austrian army, referred to in our last number,* is described at length in *Mitt. Artil. Genie-Wesens*, Part I, 1882, p. 1, and also quite fully with drawings in *Engineering* for May 19, 1882. Two different explosives were used: new dynamite No. 1, and gelatine dynamite. The first was composed of fifty-eight per cent. of nitro-glycerine, two per cent. of gun-cotton, and forty per cent. of powder mixture consisting of seventy per cent. potash saltpetre and thirty per cent. of sawdust. The gelatine dynamite (new gelatine) was composed of seventy-eight per cent. of nitro-glycerine, two per cent.

* Vol. VIII, p. 298.

of gun-cotton and twenty per cent. of the powder mixture. The charges were in quantities of 0.25 kilo and 0.50 kilo in paraffined paper, and 0.3 gram exploders were used for the new dynamite, and 0.1 gram for the new gelatine.

In the *Mém. Soc. Ingénieurs Civils*, Feb. 28, p. 238, M. Brunet gives the results of his work in the removal of submarine rocks at Cette, L'Orient, and Carthagène. He used on the average one kilo of dynamite for ten cubic metres of rock of ordinary hardness. At Frioul they disengaged, in one operation, a volume of 10,000 metres with 1000 kilos of dynamite, used in two mines.

In a review of L. Tetmajer's work entitled "Die Nobel'schen Nitroglycerin-Präparate," the *Mitt. Art. Genie-Wesens*, 5 and 6, 1882, B. A. 29, extracts the following table:

EXPERIMENTS MADE WITH TRAUZL'S MEASURE FOR EXPLOSIVE FORCE.

Substance.	Composition.	Volume in 3 cm.	Relative Strength.
Nitro-glycerine	Water free.	1380	100
Explosive gelatine.....	{ 93 per cent. nitro-glycerine. 7 " collodion gun-cotton. }	1350	100
Gelatine dynamite, No. I...	{ 58 per cent. nitro-glycerine. 2 " collodion gun-cotton. 28 " saltpetre. 12 " cellulose. }	960	70
Gelatine dynamite, No. II...	{ 38.8 per cent. nitro-glycerine. 1.2 " collodion gun-cotton. 45 " saltpetre. 15 " cellulose. }	710	52
Kieselguhr dynamite, No. I.	{ 75 per cent. nitro-glycerine. 25 " kieselguhr. }	950	70
Dynamite, No. III.....	{ 25 per cent. nitro-glycerine. 75 " saltpetre powder. }	550	40
Fulminating mercury	Alone.	300	22

Trauzl's method is by means of the lead cylinder described some time since in these Proceedings.* In these experiments the cylinder measured 20 cm. in diameter and 20 cm. in height. The charge consisted of 20 grams of the explosive and 0.4 gram of fulminating mercury for an exploder. From the table we see that as

* Vol. V, p. 25.

the results of these experiments the force of the dynamites No. I is to that of explosive gelatine as 1 : 1.42. In driving the Pfaffen Spring tunnel, where both of these explosives were used, it was found that to remove one cubic meter of rock required of dynamite 3.28 kilos, and of explosive gelatine 2.28 kilos. In a larger tunnel, to remove the same quantity of rock required of dynamite 3.80 kilos, and of explosive gelatine 2.51 kilos. Here the consumption of gelatine to dynamite for the same work was as 1 : 1.43 or 1 : 1.51.

The *Mém. Soc. Ingénieurs Civils*, May, 1882, p. 629, contains a report by M. Murgue upon the regulations to be issued concerning the arrangement and control of magazines for dynamite, in which it is urged that the tax upon dynamite in France, which now amounts to one-half the value of dynamite No. 3, should be reduced.

The dynamite cartridges heretofore issued to the cavalry and cossacks in Russia for destroying railroads and telegraph lines were withdrawn June 25, 1881, and replaced by gun-cotton cartridges. (*Mitt. Artil. Genie-Wesens*, Part 3-4, 1882, Kleine Notizen 59.)

In the *Engineering*, February 24, 1882, is an account of a launch of a large screw steamer at Kinghorn, Scotland. The launch was accomplished by means of a number of charges of dynamite placed in the wedge-blocks along the sides of the keel. These were exploded one by one, beginning at each end, and when the last of the wedge-blocks were removed, hydraulic power was applied, and the vessel glided off the ways in excellent style.

Antimony and certain other of the metals when deposited in certain states exhibit such phenomena of heat and light when struck or heated as to be termed explosive. In the *Comptes Rendus*, XCIV, Deville and Debray treat of such a substance under the title "Note on some Explosive Alloys of Zinc and the Platinum Metals." Rhodium, ruthenium, iridium and osmium all combine to form such alloys. Platinum and palladium do not. When the osmium alloy is heated to 300° C. it takes fire immediately, nearly with explosion, and gives off fumes of zinc oxide and osmic acid. The phenomena attending the change of state of the iridium alloy is so marked as to serve to detect the presence of as small quantities as one to two per cent. in the presence of platinum.

The special committee to test the explosive qualities of xerotine siccative, which comprises among others Professor Abel and Colonel Majendie, have been engaged at Chatham in the necessary experiments. Operations were first undertaken to test the force of dynamite, and for this purpose the *Enterprise*, one of the obsolete armor-plated wooden ships, was turned over to the committee. In one of the rooms a small quantity of dynamite was exploded, with the result of completely shattering all the rooms in the vicinity and injuring seriously other parts of the vessel. Other experiments were made by placing a small quantity of xerotine siccative in an iron cask and shaking the latter occasionally at stated intervals for twenty-four hours. A train having then been laid and fired, no explosion followed; but upon a light being applied there was a loud explosion. Further experiments were made by placing the siccative in water, but the latter appeared to have no effect upon it, as the siccative readily exploded when ignited.—(*Iron*, Feb. 10, '82.)

In a recent lecture on some dangerous properties of dusts Professor Abel said that many experiments were tried with sensitive coal-dust from Seaham and other collieries for the purpose of ascertaining whether results could be obtained supporting the view that coal-dust, in the complete absence of fire-damp, is susceptible of originating explosions and of carrying them on indefinitely, as suggested by some observers, but although decided evidence was obtained that coal-dust when thickly suspended in the air will be inflamed in the immediate vicinity of a large body of flame projected with it, and will sometimes carry on the flame to some small extent, no experimental results furnished by these experiments warranted the conclusion that a coal-mine explosion could be originated and carried on to any considerable distance in the complete absence of fire-damp. Some experiments made in a large military gallery at Chatham showed that the flame of a blown-out shot of $1\frac{1}{2}$ lbs. or 2 lbs. of powder might extend to a maximum distance of twenty feet, while in a very narrow gallery, similar to a drift-way in a mine, the flame from corresponding charges extended to a maximum distance of thirty-five feet. These distances are considerably inferior to those which flame from blown out shots has been known to extend, with destructive results, in coal mines, and there appears no doubt that, in the latter cases, of which the lecturer gave examples, the flame was enlarged and prolonged by the dust raised by the concussion of the explosion. In the presence of only

very small quantities of fire-damp, dust may establish and propagate violent explosions; and in the case of a fire-damp explosion, the dust not only, in most instances, greatly aggravates the burning action and increases the quantity of after-damp, but it may also, by being raised and swept along by the blast of an explosion, carry the fire into workings where no fire-damp exists, and thus add considerably to the magnitude of the disaster.—(*The Engineer*, June 23, '82.)

In an article on Modern Artillery, *Engineering* of June 16, 1882, says: "From the results obtained by the Government Committee on Explosives, and the researches of Abel and Noble on fired gunpowder, it became apparent that a high initial velocity of the projectile, together with its attendant advantages of flatness of trajectory, accuracy, power of penetration, and length of range, could only be satisfactorily obtained by generating in the bore of the gun a large quantity of gas at low maximum tension or pressure. The production of a large quantity of gas can only be effected by using large charges of powder. A reduction of the maximum pressure may be secured by using either very slow burning powder, which becomes converted into gas at a much lower rate than is the case with the powders already in use; or when using the latter their destructive action may be modified by allowing the charge to expand in a chamber very much larger than is absolutely necessary to contain it. The latter method is technically known as air spacing. It is evident that a combination of both these devices is possible. The immediate result of the employment of either or both is to necessitate the use of very long guns, so as to keep the projectile in the bore under the influence of the propelling power of the gas for as long a time as possible, thus counteracting, or more than counteracting, the want of high initial pressure. The whole result may be described as follows: "It has been found possible by the use of very slow burning powder, or of quicker burning powder duly air-spaced, and expanded in a very long bore, to about double the power of ordnance, weight for weight, and such a result does not seem to point to any finality in the path of artillery."

Col. Maitland, Superintendent of the Royal Gun Factories, Woolwich, has been lecturing before the Portsmouth Military Association on "Recent Advances in Gunmaking," and before the Society of Arts on "Modern Ordnance." From the reports in *Iron* (Jan. 20

and Feb. 17, 1882) we make the following abstracts: While the advocates of breech-loading as against muzzle-loading are right, the arguments they advance are for the most part fallacious. The real cause which has rendered breech-loading an absolute necessity is the improvement which has been made in gunpowder. The slower the combustion of the powder the less the difference in the pressures exerted at the breech and at the muzzle, and the greater the advantage of lengthening the bore, and so keeping the shot under the influence of the pressure. Hence all recent improvements have tended towards larger charges of slower burning powder and increased length of bore; and it was evident the longer the bore the greater the convenience of putting the charge in from behind. Another advantage of the new system was the facility afforded for enlarging the powder chamber of the gun, so that a comparatively short, thick cartridge might be employed without any definite restriction due to the size of the bore. Again, a shot loaded from the front must be smaller all over than the bore, or it would not pass down to its seat. A shot thrust in behind, on the contrary, might be furnished with a band or sheath of comparatively soft metal larger than the bore. The gas, then acting from the base of the projectile, forces the band through the grooves, sealing the escape in a very satisfactory way, centring the projectile and to a great extent mitigating the corroding effects of the gas. Artillerists were aware that the effect of the resistance offered by the band on the powder was to cause more complete combustion of the charge before the shot moved, and therefore to raise the velocity and the pressure.

In gun construction it should not be overlooked that the motive power is powder, and the purpose to be accomplished a hole in an armor-plate, perhaps a breach in a concealed escarp, or destructive effect on troops. No single gun is capable of realizing more than one result in the highest state of excellency. For armor-piercing a gun should have a large chamber, and a comparatively small bore of great length. For breaching fortifications a large bore without great length and no enlarged powder-chamber, and for use against troops, with shrapnel, a gun intermediate between these is required. In conclusion, Colonel Maitland remarked that there were certain axioms which were known from experience. The length of the powder chamber should not be more than three and a half times the diameter, because with longer charges the inflamed powder-gas was apt to acquire rapid motion and to set up violent local pressures. The

strength of a heavy gun should not be less than about four times the strain expected. In speaking of the benefits resulting from the employment of slow burning powders, the lecturer showed by experiment how the enlargement of the powder grains reduced the rate of combustion, and imparted their influence gradually to the projectile as it moved forward in the gun. After the lecture before the Society of Arts, Professor Abel spoke on the subject of gunpowder development.

Iron (February 24, 1882), speaking of recent experiments at Woolwich, says Colonel Maitland has taken a new departure in gunnery by giving up air-spacing as an unprofitable expedient. Having found by repeated trials the description of slow-burning powder best adapted to his requirements, he has designed a contrivance for retaining it in the chamber of the gun until the powder is sufficiently fired to set up a pressure of about two tons per square inch on the base of the shot, which then starts at a bound, its speed being accelerated until it leaves the gun by the pursuit of the powder-gases. The retention of the shot is accomplished by a ring of metal fixed around it at the base, and so regulated as to size that it will, when placed in the breech, be a trifle larger than the bore through which it has to pass. According to the resistance which it affords will be the period of retention. It has been demonstrated by experiments with field gunpowder that in a very strong vessel the powder may be ignited and converted into gas, but yet held under subjection for an unlimited time. The retention ring is made to surrender at a given pressure, and requisite conditions for the attainment of maximum velocities thus appear to have been realized. With the 10.4-inch gun a 462-pound shot has been fired at a muzzle velocity of 2275 feet per second, equivalent to 16,500 foot-tons, but as the powder charge was somewhat in excess of the service allowance, it is fair to reduce the velocity by one hundred feet. It will even then be far in advance of the speed attained under former conditions. The improvement has been shown in a competitive trial between the two experimental guns of forty-five tons, that of Elswick with the air-spaced chamber, and that of Woolwich with the retention ring. The former, with 350 pounds of powder (rather above its service charge), discharged a 700-pound projectile at a velocity of 1900 feet per second; the latter loaded with 400 pounds of powder and a similar 700-pound shot recorded a muzzle velocity of 2120 feet. These figures represent in energy

respectively 17,500 and 20,800 tons per foot, and the advantage in an attack upon armor-plates may be assessed in the same proportion.

The *Mitt. a. d. Gebiete d. Seewesens*, X, 149, describes a new powder made at the powder mills of Murcia, Spain. The mixture consists of 74 per cent. saltpetre, 16 per cent. carbon, and 10 per cent. sulphur. The form and size of the grain as well as the density vary with the calibre. For the bronze and steel 8 and 9 cm. guns it is in irregularly-shaped 6–10 mm. grains of 1.664–1.667 density. For the 14 cm. bronze and 15 cm. steel, 7-channeled prismatic powder of 1.64 to 1.69 density, and containing one per cent. of moisture, is used. The prisms are 25 mm. high and weigh 38 grams. The six sides of the ground-plan have a length of 20 mm., and the conical perforations taper from 4.8 down to 4.4 mm. The axes of the six outside perforations are 11 mm. distant from the axis of the central perforation. See also *Revue d'Artillerie*, XIX, 5, 464.

The new rules regarding the proofs for powder, for the Italian army, were approved by the Minister of War, March 9, 1881. The regulation powders are classified as follows :

Progressive Powders. These new powders, made at the Fossano powder mills, are intended for the new breech-loading siege (field and coast) guns. The grains are in the form of irregular rectangular prisms. For guns of medium calibre, that is to say of 12 cm., 15 cm. and 19 cm., the size of the grain varies between 20 and 24 millimetres; the number of grains to the kilogramme between 140 and 150, and the real density between 1.71 and 1.74.

For the 32 cm. gun the grains are from 43 to 53 mm. on the side; the number of grains to the kilo varies between 42 and 50, and the real density between 1.77 and 1.80.

Lastly, for the 45 cm. gun the grains are from 54 to 60 mm.; the number of grains to 10 kilos varies from 44 to 46, and the real density between 1.75 and 1.78.

Cubical Powder. This powder has already been used for some time for the 24 cm. gun, and also for firing rupturing projectiles in the 16 cm. G. R. C. muzzle-loading gun. The grains are nearly cubical, with rounded edges, varying in size from 9 to 11 mm.; the number of grains to the kilo is between 485 and 515, and the real density between 1.77 and 1.80.

Powder of 7 to 11 mm., being for breech-loading field guns of 7 to 11 mm., is in angular grains. The number of grains to the kilo is between 2200 and 2600; the real density 1.66 to 1.68.

The progressive powder not being suitable for small charge in guns of medium calibre they have substituted the 7 to 11 mm. powder, since ordinary cannon powder, which has been tried, has not given good results.

Ordinary Cannon Powder. This will be used for the new breech-loading mortars of 15 and 21 cm. and the *mortier rayé* of 15 cm. ret.; also for the 7 cm. mountain howitzers and all muzzle-loading guns of the old type, and also for all shells except those used in the breech-loading field guns and mountain howitzers. The grains are lamellar of 0.7 mm. to 1.5 mm. in size; real density 1.70; gravimetric density .860 to .910; number of grains to the gram 900 to 970.

Musket Powder is to be used for the cartridges for muskets, and also for the charging of all shell and shrapnel used in breech-loading field and mountain guns. The grains are lamellar of 0.4 mm. to 0.7 mm. in size; real density 1.67 to 1.69; gravimetric density 0.830 to 0.880; number of grains to the gram 4550 to 5000.

The composition of all these powders is the same, being 75 per cent. of saltpetre, 15 per cent. of carbon, and 10 per cent. of sulphur; the powders made before 1873 have different proportions. All the powders are made by the use of the drum and hydraulic press. For the *progressive* powders the ternary mixture, after having been pressed, is mixed, in a moist state, with a determined quantity (25 per cent.) of dry grained and polished powder. After granulation all these powders are polished strongly and covered with graphite.

After a preliminary examination each species of powder is subjected to the following tests: Verification of the size of the grain; measurement of the real density (and for musket and cannon powder the gravimetric density); measurement of the initial velocity; measurement of the pressure (for large grained powder only). A table of the tests they must satisfy is appended. *Revue d'Artillerie*, 19, 4, 343. *Vide* also *Giornale d'Artiglieria e Genio*, 1882, pp. 447 and 468.

For the classification of powder in Holland see *Mitt. Artil. Genie-Wesens*, Part 5 and 6, 1882, Notizen, p. 125.

Die Moderne Spreng-technick is the title of a pamphlet of 48 pp. 8°, by Robert Krause, published by G. Knapp, Leipzig, 1881, which

treats of the use of high explosives in blasting, describes, with illustrations, the way in which the fuses are to be applied and the machines employed for firing them, discusses the question of the area of explosive effect, and gives a full account of implements employed in drilling.

U. S. Census Bulletin, No. 286, on the manufacture of chemicals, states that 3,039,722 pounds of nitro-glycerine, having a value of \$1,830,417, were manufactured in the United States in 1880.

In *Iron* (Feb. 17, 1882) in an article on "Accidents in Mines," Dr. C. Le N. Foster is quoted as showing that the use of gunpowder in mining in some districts was steadily on the decrease. Amongst eighteen mines he found that where, in 1873, 217,389 lbs. of powder were used, in 1878 only 140,869 lbs. were consumed. During the same period the use of dynamite had increased from 19,159 lbs. to 88,922 lbs. Tonite had also grown in favor, and from 1875, the first year of its employment, when 100 lbs. were consumed, the sale of this explosive had extended considerably.

The Oil, Paint and Drug Reporter, Sept. 6, 1882, 551, reviews the chemical industries of Italy, from which we learn that the sulphur trade is the most important of all these industries both as regards the total production and the number of workmen employed therein. At present there are in all about 300 sulphur mines that are being worked, of which 275 are in Sicily, 20 in the Romagna, 3 in the Neapolitan States, and 2 in the former Papal dominions. It is nearly all worked in the most primitive way, by fusing the sulphur minerals with burning sulphur, which causes an average loss of about 50 per cent. of all the sulphur made in Sicily, and 43 per cent. elsewhere. Other methods of working it, such as using closed iron smelting cylinders, or superheated steam, have only been introduced in very few works.

The total quantity of sulphur produced annually for the last few years has been 400,000 tons, worth nearly eight million dollars; 21,000 workmen found employment in this trade.

The manufacture of potash saltpetre is carried on at present at two large factories in Sampierdarena and Genoa, the latter of which is under the control of the government. It is made exclusively from Chili saltpetre by double decomposition with German chloride of potassium. The saltpetre beds of former times have everywhere dis-

appeared. Besides the above-mentioned saltpetre works, a large portion of the numerous gunpowder factories make all the saltpetre they need by the same process.

For the manufacture of powder there were in Italy not long since not less than 250 powder mills, of which not many more than 100 are now running. With the exception of a few larger establishments they drag out, on the average, a miserable existence. There is an import duty of \$30 per 220 lbs. on gunpowders, so that Italian manufacturers have the privilege of putting on the market a dear and generally a very poor article. At the end of 1870 there were four dynamite factories in Italy, only one of which, that in Avigliano, is still in operation.

In an article on the Productions of the Artillery Establishments in Russia in 1879 (*Revue d'Artillerie*, XIX, 2, 175), we find that the cartridge factory at St. Petersburg made 125,329,000 cartridges and 80,000,000 primers for the Berdan musket, 30,000,000 primers for the needle gun, 2,000,000 slow matches, 595,000 time fuses, 547,000 percussion fuses, and 258,325 fuses of the Prussian model.

At the powder mills of Okhta, Chostka and Kazan 2,784,700 kilos (6,126,494 lbs.) of new powder have been made, and at Okhta and Chostka 294,858 kilos (648,687.6 lbs.) of old powder have been re-worked.

The fuse factory at Nikolaïev has furnished 4500 2-inch war fuses, 5510 3-inch signal lights, 150 incendiary fuses, 300 life-saving rockets, and 300 pyroxyline fuses. — *Vide.* also *Mitt. Artil. Genie-Wesens*, Part I, 1882, Notizen, p. 29.

Bulletin Edison Electric Light Co. No. 14, p. 15, Oct. 14, 1882, announces the installation of the Edison plant at the Government Powder Manufactory at St. Chamas, France. The officials have expressed themselves as well satisfied with its working

NOTES ON THE LITERATURE OF EXPLOSIVES.*

PROF. CHARLES E. MUNROE, U. S. N. A.

No. III.

Berthelot and Vieille have continued their investigations upon the explosive wave, and have given their results in the *Comptes Rendus*, 95, 151, July 24, 1882, under the title *Nouvelle recherches sur la propagation des phénomènes explosifs dans les gaz*, and on 199, July 31, 1882, under the title *Sur la période d'état variable qui précède le régime de détonation et sur les conditions d'établissement de l'onde explosive*. They find that the velocity of propagation for each inflammable mixture is a true specific constant, and that it is quite important to know what this is, both as regards its bearing on the theory of the movement of gases and as concerns its applications in the use of explosives. Hence they have determined the constant for a large number of substances and mixtures, and the results given are the mean of repeated observations. By means of Clausius' formula previously given,† they have calculated the theoretical velocity for each case, and the measured velocity closely corresponds with this, except where carbon monoxide is used, and where cyanogen is mixed with two volumes of nitrogen and ethylene with four volumes of nitrogen. When hydrogen is mixed with an excess of nitrogen there is also a marked retardation. The velocity of translation of gaseous molecules, which retain the total energy developed by the heat evolved by the reaction, may be regarded as a limit that represents the maximum velocity of propagation of the explosive wave. But this velocity is diminished by contact with foreign bodies; also, when the mass inflamed at first is too small and too rapidly cooled by radiation; and when the initial velocity of the chemical reaction is

* As it is proposed to continue these notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications, trade circulars, or expert testimony in infringement cases.

† Proc. Vol. VIII, p. 303.

too feeble, as is the case with carbon monoxide. Under these conditions the wave is retarded and even stopped; then the combustion propagates itself from side to side, following a slower law.

The apparatus used in these experiments was extremely delicate. The electric spark which excited the detonation, and the exceedingly light piston which received the blow at the other end of the tube, were both connected with a chronograph, which was turning at the rate of fifteen metres per second, and thus the $\frac{3}{10000}$ of a second could be measured. In addition to the experiments mentioned above, others were made by altering the position of the piston in the tube for six positions intermediate between 0.02 metre and 40.43 metres. It was found that the limit of combustibility changed with the energy of the spark; that as combustion goes on the energy may increase so that detonation results; that this can only take place when the layer of inflamed particles exerts the greatest possible pressure on the layer in contact with it, and that it is then that the inflamed gases possess the maximum energy and velocity of translation. It is possible that analogous circumstances may conspire to give to some explosions of fire damp an unusual velocity of propagation and degree of violence. The agreement between the calculated and measured velocity of the explosive wave shows that dissociation plays an unimportant rôle in these phenomena, probably because of the high pressure developed in the path of the wave, and because, also, of its brief duration.

Where these conditions exist, viz. a powerful initial cause; a sufficiently rapid chemical reaction between the gaseous constituents; a sufficient number of particles are inflamed at first to inflame the adjacent particles; the mass of the gas is so large as not to lose a marked quantity of heat by radiation; and the layer of inflamed particles exerts the greatest possible pressure on the layer of particles with which it is in contact; there we have the *dominion of detonation*. But it is easy to conceive of a totally different set of circumstances where there is a tendency to reduce to zero the pressure which the inflamed layer exerts on its neighbor, and consequently the velocity of translation of the molecules; then their energy and the heat they contain will also be reduced. In such a system the heat will be almost completely lost by radiation, conduction, contact with surrounding bodies, and inert gases, etc., with the exception of the very small amount which is essential for raising the neighboring particles to the ignition point. This is the *dominion of ordinary combustion*, and it is this which Bunsen, Schloesing, and Mallard and Le Chatelier

have studied. Of course we may have intermediate states between these.

These two states and the general conditions which define each, and their transition into the other, apply not only to gaseous mixtures, but also to solid and liquid explosives which are transformed wholly or in part into a gas at the moment of detonation.

In the *Comptes Rendus* 95, 599, October 2, 1882, Mallard and Le Chatelier continue their accounts of the investigation of the vibratory movement of flame in gaseous mixtures, in a paper entitled, *Sur la nature des mouvements vibratoires qui accompagnent la propagation de la flamme dans les mélanges gazeux combustibles*. They used the apparatus described in their previous paper,* with one end open, but they registered the progress of the flame by photographing it on a revolving cylinder, covered with sensitized paper, the rate of revolution being known, and the mixture of gases used being such as would emit sufficient actinic rays when burning. The result showed that for the first quarter of the tube the propagation was uniform, and that from that point it increased in speed, and that the regularity, duration and amplitude of the oscillations varied from point to point. The undulations took the form of sinusoids indicating a simple vibratory movement, or more complex forms, showing the superposition of several such movements. The mean velocity of propagation appears to be accelerated as the amplitude and rapidity of vibration become greater. In one experiment the explosive wave of Berthelot and Vieille was produced, and the last part of the tube was completely pulverized. The brilliancy of the flame varies with the successive phases of a vibration.

The *Journal Chem. Soc.* 237, 920, September, 1882, abstracts from a paper by Mallard, in the *Chem. Centr.* 1882, 268, on the "Danger of Gas Explosions," in which measurements of the rate of ignition in mixtures of common gas with air, and marsh gas with air, were made, confirming the results given above. He shows that there cannot be any danger from explosive mixtures travelling back in the pipe.

Under the title *Recherches sur l'emploi des manomètres à écrasement pour le mesure des pressions développées par les substances*

* Proc. Nav. Inst. VIII, p. 303.

explosives, Sarrau and Vieille have contributed a series of articles to the *Comptes Rendus* 95, 26, July 3, 130, July 17, 180, July 24, '82, in which they consider the use of Noble's crusher gauge for determining the pressure developed by the high explosives. They use *copper* cylinders, and by means of a machine similar to Rodman's, they exert a slow and progressive pressure upon the cylinder until it will support a determined load without permanent deformation, and thus determine the resistance of the cylinder for each given amount of compression. The examination of the results obtained shows that when the force exerted is between 1000 and 3500 kilos, its value may be expressed by a linear function of the compression.

By the aid of this data they deduce for the pressure the formula

$$p = k_0 + \frac{k\varepsilon}{1 + \varphi\left(\frac{\tau}{\tau_0}\right)}$$

in which

k_0 and k = two constants.

ε = the compression shown by the cylinder.

τ = the time between the origin of the movement and the production of the maximum force.

τ_0 = the duration of the compression of the cylinder by a constant force acting, without initial velocity, by means of a piston having a mass equal to m .

φ = a function which is equal to zero when the variable is zero, but increases rapidly when the variable increases.

The value of p for a measured value of ε depends then upon the ratio $\frac{\tau}{\tau_0}$. This ratio is the variable characteristic of the phenomena, and it is necessary to know it for each special case as precisely as possible.

The value of τ_0 is given by the formula

$$\tau_0 = \pi \left(\frac{m}{k} \right)^{\frac{1}{2}}$$

The value of τ is determined by a delicate instrument. This consists of a crusher gauge attached to the side of the vessel in which the explosion takes place. The piston of the gauge carries a pen which comes in contact with the smoked paper of a chronograph, to which is also affixed a vibrating fork for marking the time. This apparatus will record phenomena which occupy only the $\frac{3}{10000}$ of a second, as with some of the high explosives.

With this apparatus they find for gunpowder with a *density* of charge* of .7, a pressure of 3574 kilos per square centimetre.

The decomposition of potassium picrate in the state of powder was so rapid that τ could not be measured, but it was recorded when compressed blocks were used. For a *density of charge* of .3 the pressure was 1985 kilos.

Gun-cotton exploded so rapidly that τ could not be measured, and an increase in the mass of the piston produced no effect.

Dynamite decomposed more slowly than either gun-cotton or picrate of potash, and the value of τ varied with the mass of the piston. With a piston of 4 kilos, and a *density of charge* of .3, the pressure was equal to 2547 kilos per square centimetre.

The value of this method of investigation is shown in the fact that when a piston of 59.7 grammes was used for both dynamite and potassium picrate, and when the *density of charge* was .3 for each, the copper cylinder was compressed equally by each; yet it is found that for a *density of charge* of .3, the maximum pressure is 2547 for dynamite, while it is only 1985 for potassium picrate.

Commander Allan D. Brown, U. S. N., contributes a very readable article entitled "Explosions and Explosives," to the *Popular Science Monthly* **21**, 6, 773, Oct. 1882. Passing over the popular descriptions of the methods of preparation and characteristics of the different well-known explosives, we quote what he says concerning gum-dynamite or explosive gelatine, since he has recently had unusual opportunities for becoming familiar with this new explosive.†

Collodion gun-cotton is finely shredded, generally by hand, and placed in small quantities at a time in the nitro-glycerine, which is kept at a temperature of 80° F by means of a water-bath, the whole being constantly stirred with a wooden spatula; the proportion of materials is seven per cent. by weight of the gun-cotton to ninety-three per cent. of the nitro-glycerine. The latter dissolves the former, and the result is an elastic, gelatinous, semi-transparent mass, which is easily cut or torn apart, and shows no trace whatever of nitro-glycerine on handling. Its explosive properties are unaffected by contact with water, and in this respect it is the most useful of all the high explosives for military purposes. With the change in the physical condition of the two components comes also a change in

* Proc. Nav. Inst. Vol. VIII, p. 441.

† Vide Proc. Nav. Inst. Vol. V, p. 21, and Vol. VII, p. 473.

the ease of explosion ; these two bodies, each of itself highly explosive, form when united one which is quite the reverse. When unconfined, a primer of fifty grains of fulminate will cause the explosion of but a very small portion of a charge, the rest being torn in pieces ; if, however, it be strongly confined, so that the blow of the fulminate exerts its whole force, which is propagated through the gelatine, it then explodes with a violence as great as that of nitro-glycerine, if not somewhat greater. This latter point has not been fully determined, but the probabilities are that the expansion of the constituents of the gelatine is more complete and is accompanied with more heat than is the case with nitro-glycerine alone. The gelatine freezes at 40° F., and in this state is fired with no difficulty whatever, being in this respect much superior to dynamite. When subjected to a pressure of two hundred and fifty pounds to the square inch, no nitro-glycerine is separated ; the union between the two constituents seems to be complete and definite. If subjected to the action of flame it takes fire less readily than dynamite, but burns very much like it, with perhaps a greater strength of flame, as if urged by a bellows. When heated to 100° it softens, but does not become at all greasy, and there is no exudation of nitro-glycerine. Explosion by the application of heat takes place at about 420° ; but it is found that by the addition of a small amount of camphor, say four per cent., it will bear an increased heat of 100° before explosion. Experiments made with the gelatine thus camphorated show that the camphor exercises no deleterious effect upon the strength of the material, while rendering it less like jelly, and more like that form of confection known as fig-paste. Six per cent. of camphor may be added without harm, but any greater quantity materially diminishes the explosive effect. Portions of this gelatine, both pure and camphorated, have been subjected to a constant heat of 100° for more than six weeks, and no exudation of the dangerous nitro-glycerine has been observed. It will not explode under circumstances which ordinarily render certain the detonation of either nitro-glycerine or dynamite, that is to say, a quantity of gelatine will resist the shock of the detonation of another quantity placed within a few feet of it ; if very near it may take fire and burn, but detonation will not ensue unless the two masses are almost in actual contact, and even then it will not always occur. It further possesses the property of permitting the impact of a ball from a gun without exploding, while both dynamite and gun-cotton may be readily detonated by a blow of this kind. All these tests tend to show

that it possesses in a high degree the elements desired in the ideal high explosive for military purposes, if not for commercial use.

So much difficulty was encountered in the first attempts at the construction of a suitable primer for its explosion, that it seemed doubtful whether it would ever be a practicable material, as it was thought that nitro-glycerine must be used to accomplish the desired result. Subsequent experiments conducted in this country have shown, however, that a dry gun-cotton fuse with a fulminate cap, containing twenty-five grains, will fire the gelatine with ease and certainty, even when unconfined. The problem so long confronting the manufacturer of explosives would seem to be nearly solved; the requisites of greater power in small compass, of permanency when subjected to tropical heat, of ease of firing when but slightly confined, of safety from the explosion of neighboring masses of the same or on being struck by a projectile, and of not being affected injuriously by water, all seem to be fulfilled by this agent in a manner more complete than by any other.

If it should be found that a long-continued exposure to heat tends to produce decomposition, as may prove to be the case, greater care in the preparation of the materials from which it is manufactured will probably overcome this difficulty, and it will then bid fair to supersede gun-cotton for very many purposes, if it does not altogether take its place.

Through the courtesy of the author we have received a copy of a *Report on Vigorit Powder*, by Lieutenant W. R. Quinan, 4th Artillery, U. S. A., general superintendent of the California Vigorit Powder Company, and we take pleasure in commending the report as greatly superior to those generally issued by manufacturing companies, since it possesses real technical value. The methods employed for testing the strength of the powders, though not wholly new and somewhat rough, are quite ingenious and sufficiently trustworthy for the object in view. The iron plate and éprouvette tubes were discarded as delusive or as being advantageous to slow-burning powders, and a simple form of the "Crusher Gauge," with lead cylinders, was employed.* This gauge consisted of a heavy iron base, supporting four vertical wrought-iron guides, which were connected at the top by a ring. The lead plug is placed on the base, a piston weighing 12½ lbs. rests on the plug. The top of the piston is hol-

* Henry S. Drinker, *On Tunnelling*, p. 77.

lowed out to receive the charge, and over this is placed a $34\frac{1}{2}$ shot of tempered steel. The shot is bored through its axis to receive a capped fuse. All these parts are between the guides, and when the charge is fired the piston is driven against the plug, while the shot is thrown out in the opposite direction. To determine the pressure exerted in compressing the plug a given amount, a foot-pound machine was constructed similar in form to a pile-driver with a graduated scale, the shot of the pressure gauge serving for the hammer and the piston of the gauge for the anvil. This form of apparatus realizes more perfectly than any other the conditions which exist when explosion takes place in a confined space. Tests were made of cast and drawn lead plugs. The cast lead ones were unsatisfactory, while the drawn ones gave very regular results. An apparatus similar to the foot-pound machine was used for testing the sensitiveness of the powders to percussion, and, with the addition of a gas pipe and wooden tamping rod, to tamping. With this tamping apparatus the vigorit powder, as now made, withstood more than a dozen blows of 300 foot-pounds each. The ability to tamp a powder is regarded as quite important, since it enables the miner to put the powder where it will do the most efficient work, hence a powder which can be tamped freely will be found more economical than one which is too sensitive to be tamped at all.

The friction apparatus consisted of a heavy block covered with sand paper, resting on a board covered in a similar manner. By means of a long handle the block could be drawn backward and forward. The relative leakage of nitro-glycerine from the various powders was determined by placing equal weights upon weighed slips of bibulous paper for equal times, and then measuring the increase in weight of the papers.

Tests as to the effect of fire were made by ramming vigorit powder into an iron pipe until the pipe showed signs of yielding under the pressure. One end of the pipe was stopped by a wooden plug tightly driven in, and the open end was lighted by a match. The powder burned without explosion. Again: a large cartridge was placed in a small strong box, the lid being securely fastened with screws. A fuse, passing through a small hole in the side of the box, served to light it. The cartridge burned up without explosion, the box being badly charred on the inside, but not broken.

Lieutenant Quinan regards the property of deliquescence as a most serious one in mixed powders. The progress of deliquescence is

thus explained. The air confined in the cartridge contains a slight quantity of moisture, which, in uniting with the salt, causes a depression in temperature, which condenses fresh moisture from the surrounding air. This being taken up, reduces the temperature still more and brings a fresh supply, and so on. The process continues till arrested by an outside elevation of temperature, when the action is reversed. In losing moisture, the heat rendered latent is given out, raising the temperature, which causes a fresh loss of moisture and further elevation of temperature, and so on, till a change in atmospheric conditions arrests this process and induces a contrary. This gives two different and incompatible characters to a powder in which deliquescent salts are used, depending upon the particular state in which it is taken; when absorbing moisture it is comparatively weak and insensitive to blows or compression; when losing moisture it is comparatively strong and very sensitive to both. The temperature being already elevated, a slight blow will raise it to the exploding point. The compression given by the tamping rod in compacting it in the bore-hole may be sufficient to cause a premature explosion. These qualities render the powder unfit to bear climatic changes, and especially dangerous in warm or drying weather. Its constant subjection to chemical action gives it a character of instability especially conducive to disasters in handling it. The powder which is safe to-day and dangerous to-morrow is the most dangerous of all.

The effect of heat on all powders is to bring them nearer their exploding points, and thus to increase their sensitiveness. This heat makes a slight saving of work in explosion—so that all explosives are a little stronger in warm weather. The danger of deliquescent ingredients is not in lowering the firing point of nitro-glycerine, but of elevating the temperature of the powder to a dangerous approximation to this point.

The author holds that while in dynamite, the absorbent being inert, the force is dependent upon the amount of nitro-glycerine present, the more modern powders do not depend entirely on this. Citing the experiments of Roux and Sarrau, which showed that if a fulminate acted through the medium of nitro-glycerine an explosion of the first order would be produced, he argues that a mixture of nitro-glycerine with the ingredients of gunpowder will develop a much greater force than the sum of the forces of the two fired separately. In this he differs with Hill and Mowbray, while he is supported by Drinker. He also claims that anything in a powder which interferes

with the transmission of the detonating impulse or wave will cause a diminution in strength through imperfect detonation. It requires 60 per cent. of nitro-glycerine to make a powder of kieselguhr which can be depended upon to explode at all. As the nitro-glycerine is increased the strength increases rapidly, through better transmission of the impulse. Even taking 75 per cent. as the utmost which the powder will safely hold, the detonation is not perfect under ordinary conditions, though it approaches it more nearly as the impulse is concentrated by stronger confinement.

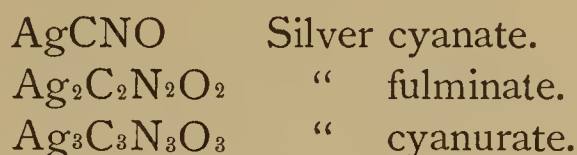
The name of this powder illustrates the different uses to which a name is put in commerce. Formerly the name Vigorite was applied to the nitrated cane-sugar discovered by Sobrero. In the last number* of these Proceedings the composition of a powder called Vigorit was given. The powder of the same name reported on by Lieutenant Quinan has still a different composition.

One of the results of modern activity in chemical research has been the discovery and recognition of the existence of many groups of substances, each member of which is composed of the same number of the same kind of elements, and possesses the same molecular weight, while the properties of the different members of the group are quite unlike. Such substances are called *isomeric* bodies. Again, other groups of bodies have been noticed which, while having the same percentage composition, possess in the higher members of the series a molecular weight which is a definite multiple of the lowest member of the series. Such substances are called *polymeric* bodies. The fact that these bodies exhibit different properties while having the same percentage composition, is explained by chemists as being due to a difference in the arrangement of the atoms in the molecule. It is a matter of great importance and interest to discover what this arrangement is, and this work now engages the attention of many chemists; but it can readily be seen that it must be surrounded by considerable difficulty, since we aim to learn the order of arrangement of inconceivably small atoms in not much larger molecules. This is reached, where it has been done, by a study of the reaction between the substance under consideration and other substances, and of the products of the reaction, and of its derivatives and replacement products, also of the various methods of production. Again, its various physical properties have been carefully studied. Through

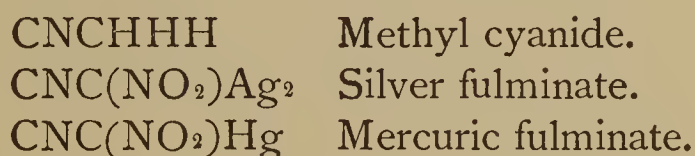
* Vol. VIII, p. 444.

the consideration of the results of all these methods a knowledge of its constitution has been gained.

Mercuric fulminate belongs to such a polymeric series, which may be represented for the silver salts by



Mercuric fulminate was discovered by Howard in 1800, but the composition remained unknown until 1824, when Liebig analyzed it and the silver salt, and got a percentage-composition agreeing with the above formula, and in this he was confirmed by Gay-Lussac. They both agreed on the formula for the silver salt, and consequently for the mercury salt also, of $\text{Ag}_2\text{C}_2\text{N}_2\text{O}_2$, since silver cyanate was already known to have the simpler formula. Berzelius considered the fulminates as containing a metallic nitride (*e.g.* AgO , AgN , C_4NO_3) as this afforded an explanation of the fact that in many reactions, as with fulminating silver, only half the metal is separated. The detonation was attributed to the metallic nitride. Owing to the formation of the fulminates through the action of nitric acid and alcohol, together with the fact that they were explosive, induced Laurent and Gerhardt to regard them as compounds containing nitryl (NO_2), since nitric acid frequently introduces this radicle into organic molecules, and this often imparts to them an explosive character. Kekulé's study on the products of decomposition of fulminating mercury, and Schischkoff's on fulminuric acid, support Laurent and Gerhardt's views, and Kekulé writes the formula in accordance with these results thus $\text{C}(\text{NO}_2)(\text{CN})\text{H}_2$. According to this, fulminic acid and the fulminates belong to the same type as marsh gas, thus



Schischkoff doubles these formulas for the fulminates, but otherwise agrees to them.

From the abstracts *Jour. Chem. Soc.* **237**, 816, August, 1882, we learn that E. Carstanjen and A. Ehrenberg publish in *Jour. Prakt. Chem.* [2] **25**, 232, a paper on mercuric fulminate, in which its action toward a large number of chemical agents is noted, and certain deriv-

ative fulminates described. When treated with various acids it was decomposed with formation of a mercury salt, carbon dioxide and a *hydroxylamine* salt. With hydriodic acid ammonium iodide was one of the products, and with boiling dilute sulphuric acid mercury *oxalate* was formed. A number of experiments were made to determine which form of cyanogen exists in mercuric fulminate, but the results do not yet seem to lead to an issue.

In a paper in *Comptes Rendus*, **94**, 1114, April 17, 1882, entitled *Sur quelques réactions des sels de protoxyde d'étain*, A. Ditte describes the formation of silver meta-stannate ($5\text{SnO}_2 \cdot \text{Ag}_2\text{O}$), which has a red color, and detonates, when heated, with the development of heat and light. This detonation is transmitted along a train of the compound, as in the case of gunpowder.

An experiment described by A. Villiers, *Comptes Rendus*, **94**, 1122, April 18, 1882, under the title *Sur le bromure d'éthylène tétranitré*, shows, very curiously, how limited the conditions are under which explosion may take place. He mixed ethylene bromide in a retort with about an equal volume of fuming nitric acid, and heated the mixture, when an energetic reaction took place, and oxides of nitrogen, nitrosyl bromide, and bromine were evolved. At first the ethylene bromide dissolved in the acid, but after a time the liquid became turbid and separated into two layers. At this point the reaction became explosive, and the lamp was withdrawn and the retort cooled by cold water. The liquid was afterward distilled almost to dryness, but *when the lamp was withdrawn and the temperature of the mixture consequently lowered, the reaction again became explosive*. The result of the reaction is the formation of tetranitroethylene bromide, which is obtained as canary-yellow crystals, which when heated to 145° detonate (mercuric fulminate detonates at 186°), but do not explode by percussion.

M. Vieille presents a paper to the *Comptes Rendus*, **95**, 123, July 17, 1882, entitled *Sur les degrés de nitrification limites de la cellulose*, in which he shows that the degree of nitrification depends upon the strength and amount of the nitric acid present, and the length of time (in most cases) the cotton is exposed to its action. He used pure nitric acid of different measured strength, and immersed the cotton in it at 11° , 100 to 150 times as great weight of nitric acid

being taken as of cotton used. The amount of nitrogen contained in the product was then determined by Schloesing's method. With nitric acid sp. gr. 1.450 the mononitrocellulose was obtained yielding 108 cc. of nitric oxide. Nitric acid sp. gr. 1.502 gives a nitrocellulose which yields 202.1 cc. of nitric oxide, and which is soluble in acetic ether and alcohol-ether solution. Only a mixture of nitric with sulphuric acid will furnish military gun-cotton. With such a mixture at 11° a cotton was obtained which was completely soluble in acetic ether, but completely insoluble in alcohol-ether, and which yielded 214 cc. of nitric oxide. If the formula be



theory requires 215.6 cc. An excess of sulphuric acid retards the rapidity of the reaction, while Nordhausen sulphuric acid proved no more serviceable than any other. The mononitrocellulose was obtained as a friable paste which was insoluble in both acetic ether and ether-alcohol solution.

Some years ago an article went about the press describing a novel kind of gunpowder which possessed great power, and was said to have been adopted by the Prussians. It was composed of sawdust and nitre in certain proportions, and was thought to be harmless in this condition. To render it explosive, enough sulphuric acid was added to make it cohere, and when dried it was ready for use. Cheapness, simplicity in manufacture and safety were claimed for this powder, and it was said to leave little residue when fired. It does not, however, seem to have come into use.

On the 28th of January, 1876, an explosion occurred on the premises of the Triumph Safety Powder Co., in Baltimore, Md. Fire Inspector Holloway held an examination, before which the inventor and stockholders swore to the nature and composition of the powder, and on the 31st he gravely reported that "the safety powder is a chemical compound made of the following ingredients: nitrate of soda or potash, sulphur, peat or charcoal, or hard coal with oily matter, vegetable, animal, or mineral, or tar, or any substitute thereof. Its process is to make a solution of the nitrate; mix it with highly dried peat and oleaginous matter and sulphur, and boil it under superheated steam at temperature of 250 F. during about one hour until the watery element is rarified. Then the compound becomes

thick, and the temperature is slowly reduced from 250° to 150° F., when the compound is finished to be dried."

"By the solution of sulphur and nitrate in contact with the oily matters a certain portion of nitro-glycerine or nitro-tar is produced in its latent and safe state, which is incorporated in the whole mass, and makes the powder inexplosive in the open air, and also doubles its dynamical power. At all the numerous tests to which it has been subjected those qualities have been fully demonstrated, and in none more satisfactorily than at the said fire."

Experiments have been made at Cherbourg with a new explosive invented by Eugene Turpin, called "Panclastite" or "Brise-tout." It is said to be composed of two liquids, each non-explosive when alone, but when mixed together, just as wine and water are mixed, a fulminating compound is produced which can be exploded either by ignition or percussion. The experiments made by the iron plate and the lead cylinder tests showed it to be much more powerful than dynamite, while by trial it was shown to be much less sensitive to a blow.—*Rivista Marittima*, 25, 10, 143, October, 1882.

From the meagre description given we are unable to learn the composition of this explosive, but it appears to be of the same nature as those invented by Dr. Sprengel.—*Chem. Soc. Jour.* [2] 11, 796. These are mixtures of a combustible and an oxidizing substance which can be kept separate during transport and mixed only when required for use. A mixture of nitro-benzine or of picric acid with nitric acid (sp. gr. 1.5) are types of the class. When fired by a detonating cap they explode with a violence which is only comparable with that of nitro-glycerine. The liquid state, the corrosive character of nitric acid and its ready solubility in water, are all serious objections to these explosives.

Prof. T. W. Tobin in lecturing on *Explosive and Dangerous Dusts* before the Fire Underwriters Association of the Northwest, experimentally illustrated the way in which the dust of flour and other mills gives rise to explosions, and cited data to show that these explosions are most likely to occur during a period of high temperature, high barometer and marked absence of humidity. Among other cases recorded were the explosion of starch in a candy factory in Minneapolis, of barley in the Ehret brewery, and of sawdust in the Pullman Car Works.—*Jour. Franklin Inst.* [3], 84, 6, 412, December, 1882.

Through the courtesy of the Office of Naval Intelligence we have received a copy of a pamphlet entitled *The Doterel Explosion*,* by Thomas Rowan, C. E., E. & F. Spon, London, 1882. After criticising severely the reports of the various boards appointed to investigate the explosions on the Doterel and Triumph, and describing the internal arrangement of the ship and her stores by the aid of diagrams, he discusses the probability of the explosion being due to gas from the coal, and dismisses this as unlikely, since the ship was nearly out of coal; the bunkers were ventilated; no rise in temperature was noted in the bunkers where the temperature was taken every four hours; the bunker lids were probably off, as the order had been passed to prepare for coaling; too long a time had passed since coaling, as explosions usually occur within three days, and the longest time recorded is of an explosion which occurred thirteen days after coaling; and finally *no explosion took place abaft the magazine where the coal bunker was placed*.

In the fact that xerotine siccative was stowed in the mast-hole close to the fore magazine; that xerotine siccative contains benzoline; that benzoline is very volatile at ordinary temperatures (viz. 50° to 60° F.), yielding a vapor which readily diffuses with air, forming with it a most dangerous mixture, one volume of benzoline with 60 volumes of air being highly inflammable, and with 30 volumes highly explosive; and that on the day previous to the explosion *the magazine had been opened on two occasions*, allowing the inflammable mixture an opportunity to drift into the magazine, the author finds all the conditions necessary for an explosion. All that remained necessary was that the gas should be fired. The conditions here presented were such as Colonel Majendie found existed on the canal boat Tilbury, which exploded in Regent Park, October 2, 1874. On board the Tilbury, prior to the accident, were five tons of gunpowder and four barrels of benzoline in the hold. Communicating with the hold by means of a small ventilating hole was the after-cabin, and in the cabin a small open stove. Benzoline vapor from the barrels made its way into the cabin and was ignited, and an explosion of the vapor in the hold ensued, and the gunpowder exploded thirty seconds after. So in the Doterel there were two explosions.

At the Royal Powder Works at Spandau, Prussia, frequent ignition of the powder at a certain stage of the process led to an exami-

* *Vide* Proc. Nav. Inst. Vol. VIII, 313 and 459.

nation of the machinery, when it was found that where at certain parts, bronze pieces, which were soldered, were in constant contact with the moist powder, the solder was much corroded, and in part entirely destroyed, and that in the joints a substance had collected which, on being scraped out with a chisel, exploded with emission of sparks. It was suspected that the formation of this explosive material was in some way connected with the corrosion of the solder, and the subject was referred for investigation to Rudolph Weber, of the School of Technology at Berlin. The main results of his investigation are as follows :

The explosive properties of the substance indicated a probable nitro-compound of one of the solder metals (tin and lead), and as the lead salts are more stable and better understood than those of tin, it was resolved to investigate the latter, in hope of obtaining a similar explosive compound. Experiments on the action of moist potassium nitrate or pure tin led to no result, as no explosive body was formed. Stannous nitrate $\text{Sn}(\text{NO}_3)_2$, formed by the action of dilute nitric acid on tin, has long been known, but only in solution, since it is decomposed on evaporating. By adding freshly precipitated moist brown stannous oxide to cool nitric acid (sp. gr. 1.20) as long as solution occurred, and then cooling the solution to -20° , Weber obtained an abundance of crystals of the composition $\text{Sn}(\text{NO}_3)_2 + 2\text{H}_2\text{O}$. They resemble crystals of potassium chlorate. They cannot be kept, since they liquefy at ordinary temperatures. An insoluble *basic* salt was obtained by digesting an excess of moist stannous oxide in a solution of stannous nitrate, or by adding to a solution of stannous nitrate, by degrees, with constant stirring, a quantity of sodium carbonate insufficient for complete precipitation. Thus obtained, the basic salt, which has the composition $\text{Sn}_2\text{H}_2\text{O}_7$, is a snow-white crystalline powder, which is partially decomposed by water, and slowly oxidized by long exposure to the air or by heating to 100° . By rapid heating to a higher temperature, as well as by percussion and friction, it explodes violently, giving off a shower of sparks. This compound is also formed when a fine spray of nitric acid (sp. gr. 1.20) is thrown upon a surface of tin or solder. It is also formed when tin or solder is exposed to the action of a solution of copper nitrate, and thus formed, presents the properties already described.

In this, then, we have a probable cause of the explosions occurring in the powder works ; but the explanation of the formation of the substance is wanting, as potassium nitrate was shown not to give an

explosive substance with tin. A thin layer of a mixture of sulphur and potassium nitrate was placed between sheets of tin and copper foil, and allowed to stand, being kept constantly moist. After a time the copper was found to have become coated with sulphide, while the tin was largely converted into the explosive basic nitrate. The conditions are obviously the same as those found in the powder machinery, where bronze and tin solder are constantly in contact with moist gunpowder. The chemical action is probably this: the sulphur of the powder forms with the copper of the bronze, copper sulphide; this is oxidized to sulphate, which reacts with the nitre of the powder, forming potassium sulphate and copper nitrate; the latter, as shown above, then forms with the tin of the solder the explosive basic nitrate, which, being insoluble, gradually collects in the joints and finally leads to an explosion.—*Am. Chem. Journal*, Notes, 4, 4, 327, Oct., 1882; *Jour. für praktische Chemie* [2], 26, 121.

The product of the Spanish Powder Mills for 1882 is fixed at 222,000 kilos, divided as follows: For the powder mills of Murcia, 60,000 kilos of prismatic powder, part with one and part with seven perforations, 30,000 kilos of 6 to 10 mm. powder, and 30,000 kilos of pebble powder. At the Granada Powder Mills, 12,000 kilos of prismatic powder and 90,000 kilos of reworked musket powder.—*Mitt. Artill. u. Genie-Wesens*, 1882, *Kleine Notz*, 203.

Extra Census Bulletin of the United States, entitled *Report on the Manufacture of Firearms and Ammunition*, fixes the value of the product of ammunition for 1880 at \$1,929,966, the number of establishments in operation at five, and the capital invested at \$834,000. This manufacture is described as being characterized by the use of methods which are distinctively American in their origin, and marked by great ingenuity, a wonderfully prolific output, and a quality surpassing anything approached by methods employed in foreign countries, or in any country prior to the past decade. Brass and copper shell cartridges did not come into use until some thirty years ago, when their importance in making gas-tight joints in breech-loading systems began to be recognized. The prominence which their manufacture has now attained in this country in supplying foreign nations with ammunition is due not only to the ingenuity which has developed the mechanical methods employed, but also to the purity and ductility of the American copper used in the manufacture.

Since cartridges have been found to deteriorate from the chemical action taking place between the salts of the gunpowder and the material of the shells, means have been sought to prevent this, and the shells are now coated, by an ingenious automatic machine, with an impermeable elastic varnish. The description given of this machine, as well as of the various processes employed in the cartridge manufacture, is quite interesting.

NAVAL INSTITUTE, ANNAPOLIS, MD.

MAY, 1883.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

PROF. CHAS. E. MUNROE, U. S. N. A.

No. IV.

By far the most complete and valuable original contribution to the study of explosives which has been made in this country is the work of General Henry L. Abbot, Eng. Corps, U. S. A., which has been published by the War Department, under the title "Report upon Experiments and Investigations to develop a System of Submarine Mines for defending the Harbors of the United States," being No. 23 of the Professional Papers of the Corps of Eng., U. S. A. In a quarto of 444 pages, fully supplied with illustrations, diagrams and tabulated data, General Abbot gives the results of thirteen years of experimental investigation and mathematical study of the data thus obtained.

The chief end of all the experiments was the determination of the distance at which a given charge of a given explosive would crush a ship of war as now constructed. Starting with an empirical formula, with its undetermined constants and its variables, embracing the various conditions involved in the explosion under water of mixtures and compounds converted almost instantaneously into gas, General Abbot has, by comparison and analysis of the measured results of a large number of experimental trials, brought it to a definite and determined form, giving a final expression for the absolute shock of the explosion as conveyed through water at different distances, at different depths, and in different directions. Incidentally other questions of interest have arisen for solution and have met with experimental inquiry.

* As it is proposed to continue these notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, trade circulars, or expert testimony in infringement cases.

The first step in the investigation was naturally the experimental determination of the force of a unit weight of each explosive, and it became necessary to examine the relative value of the dynamometers available for the measurement of this force. The two forms which meet with general acceptance are Rodman's pressure gauge and Nobel's crusher gauge. Accepting the latter as more suitable for these experiments, it was decided to use lead cylinders, formed by casting and compression, to register the crushing force, rather than copper, since the latter metal is too hard for use in registering very small pressures even when a large diameter of piston is used. The requisite degree of sensitiveness was secured by employing five different sizes of lead cylinders to register the work of the explosion as transmitted by the piston, and to further extend the scale three different sizes of piston were adopted. To measure the compression of the cylinders, use was made of a standard scale having one fixed and one sliding contact piece, and reading by a vernier correctly to one-thousandth of an inch. The rapidity and accuracy of this method leave nothing to be desired.

The mathematical problem of so interpreting the lead compressions effected by a subaqueous explosion as to derive from them a correct idea of the destructive effect likely to be exerted upon a ship, required careful consideration.

At the instant of explosion, a certain quantity of gas, depending upon the nature and weight of the charge, is developed with a degree of suddenness varying with its chemical composition and the mode of ignition. The free expansion of this gas being resisted by the inertia developed in the water, a certain amount of mechanical work is instantaneously performed, resulting in the formation of a chamber filled with the highly heated products of the chemical reaction. The pressure of the surrounding water, joined to the original impulse, gives a rapid motion to this chamber along the line of least resistance, which in general coincides with the vertical drawn through the centre of the charge. A rush of gas and water into the air is the result; which, in the case of a large charge exploded near the surface, often presents an imposing spectacle. This phenomenon is analogous to what occurs at the discharge of a cannon. The line of least resistance corresponds to the axis of the bore, while the water around plays the part of the metal of the gun.

A vessel in the vicinity may be exposed to three distinct dangers: 1st. Its hull, embedded in the aqueous cannon, may be ruptured by

the initial shock transmitted from molecule to molecule through the fluid. 2d. Should the hull be situated near the vertical through the charge, its resistance may prove to be less than that of the superincumbent water; and the line of least resistance may thus be deflected from its normal direction and traverse the vessel. 3d. In the case of the enormous charges sometimes employed in submarine mining, the waves generated by the explosion may rack the vessel beyond its power of endurance, or by rising amidships may even break her in sunder.

Unless an actual vessel be available for the experiment it is evident that the pressure-gauge can only be arranged to measure the first of these three causes of destruction. The instrument virtually forms part of the aqueous cannon and chiefly registers the kinetic energy transmitted from molecule to molecule of the fluid. Fortunately this is the primary cause of rupture, and conclusions based upon the gauge indications may therefore be accepted at the best attainable of the destructive force of the explosion.

To rupture the bottom of a vessel is to perform mechanical work; that is, there must be an effective motion of the point of application of the force along the line of its direction. This motion being much greater than in the bursting of a cannon, *time* becomes a more important element. Hence in comparing different explosives under varying conditions as to distance, submergence, mode of ignition, etc., regard must be had to the amount of mechanical work to be performed, rather than to the intensity of the forces developed; but it must not be forgotten that a certain amount of the latter is needful to overcome the resistance of the hull suddenly, before the available energy can be dissipated upon the water or upon a general lateral movement of the ship. In fact, it is possible to conceive that with the same potential energy an explosion may be so sudden and short-lived as to fail to supply the continuous force necessary to effect the destruction of the hull; or, on the other hand, that its force may be developed so slowly as to be expended in general harmless motion. It would appear, therefore, that the *mean intensity* of the force acting upon the ship during the time of explosion is the quantity most important to be determined.

In 1865 Prof. W. H. C. Bartlett, in a paper read before the National Academy of Sciences, criticized the method of Rodman of attempting to evaluate the cut produced on the copper in the gauge of a gun by a comparison with the cut produced by pressure in his machine, and

he pointed out the difference in effect which must necessarily exist between the dynamic action of the gases and the static pressures of the machine. To avoid this error Gen. Abbot constructed a pendulum of considerable weight, and fixed his crusher gauge rigidly at such a point that it would receive the full force of the blow from the hammer falling through a measured arc. The value of the compression of the cylinder was thus determined in foot pounds. To connect this with the mean pressures recorded by the Rodman machine he exposed copper disks to the action of the Rodman indenting tool under the same circumstances. Other improvements were the invention of a device to exclude water from the gauge and a clutch to prevent the hammering of the piston.

Two forms of apparatus were employed for holding the gauges during the experimental explosions. First, the Ring apparatus, devised by Major King in 1865, of which four sizes, 3, 4, 5 and 8 feet respectively in interior diameter, were employed. They were made of the best wrought iron 1.5 inches thick and 4.5 inches wide in the plane of the ring. Each ring held six gauges equidistant from each other, and the ring was suspended vertically. The buoy supporting the ring had also a gauge inserted in its bottom. Second, the Crate apparatus, used for measuring the energy developed by an explosion in the immediate vicinity of the torpedo, and at certain points vertically over it. It consisted of a rectangular wrought iron frame 50 feet long, 10 feet wide and 10 feet deep, and it carried 36 gauges. The two buoys supporting it were also each supplied with a gauge. In the course of the experiments it became evident that the gauges must be held rigidly in position, and this condition was fulfilled in the Crate apparatus. In both apparatuses the charge was held in the centre. Charges of from 5 to 50 pounds of dynamite were used with the crate, and it was finally destroyed by a charge of 100 pounds. Experiments were also conducted against wooden and iron targets representing a section of a modern ship of war.

The height and form of a jet of water thrown into the air by a given charge is observed to vary enormously with its submergence, and is probably a delicate index of the combined effect of all the forces transmitted to the surface of the water. It might seem that this feature could be turned to account in studying certain important matters, such, for example, as the effect of varying the strength of case for gunpowder charges, and Capt. Vandeveld, of Holland, based his system of subaqueous measurements upon it. The subject was care-

fully investigated both instrumentally and by the aid of instantaneous photography, and it was found that the disturbing action of even very slight currents of air; the varying effects dependent upon the relative position of the sun, the jet, and the observer; the excessive tenuity of the ill-defined cloud of mist which shrouds the main body of water; and, lastly, the rapidity with which the different phases succeed each other, combine to throw too much uncertainty upon the phenomenon to render it a safe basis for important practical conclusions.

In using the Ring apparatus with explosive *mixtures* it was observed that in each individual shot there was a decided maximum intensity in *some* direction, owing probably to the case holding the charge giving way at that point, but the study of the final results proved that, with explosive *mixtures*, there is no well-marked difference in the initial intensities of action in different directions in a vertical plane passing through the centre of explosion, when the number of observations is sufficiently multiplied to eliminate the disturbing effect of anomalies.

In the study of the characteristics of the subaqueous explosions it was determined to examine fully only one typical explosive of each class, trusting that a few shots, carefully planned, would develop the peculiarities of others of the same general nature. Mortar powder was selected as a fair type for chemical mixtures, and dynamite No. 1 for chemical compounds. For comparison with mortar powder other varieties of gunpowder, together with Oliver powder (in which part of the carbon was replaced by uncarbonized peat) and the Oriental Safety compound (consisting of gambier and potassium chlorate), were taken. In order to compare the strength of dynamite No. 1 in subaqueous explosions with that of other explosive compounds, shots were fired with gun-cotton, dualine, nitro-glycerin, dynamite No. 2, mica powder, vulcan powder, rendrock, hercules powder, electric powder, Désignolle powder, Brugere or picric powder, and explosive gelatine.

In comparing the results obtained for pure nitro-glycerin with those for dynamite No. 1 there was revealed what at first sight appears to be a paradox. One pound of pure nitro-glycerin was found to exert only 81 per cent. of the intensity of action of three-fourths of a pound absorbed by an inert substance which could add nothing to the heat or gases developed. This fact, which was discovered early in the trials, was considered so extraordinary as to require careful

verification and study. The first explanation suggested was that it was due to a possible variation in the strength of the nitro-glycerin itself depending upon a difference in the chemical composition of different samples. This was tested practically with different nitro-glycerins and with nitro-glycerin and dynamite made from it, and it was shown, beyond question, that variations in the quality of the nitro-glycerin had nothing to do with it, and that the explanation must be sought in the physical conditions of the problems. General Abbot, therefore, suggests that in granulating nitro-glycerin, by absorbing it in kieselguhr, the particles of silica slightly retard chemical action,—since in detonation the reactions occur within the molecules,—and as the resistance opposed by water is of a slightly yielding character, more time may be required to reach this condition than is afforded by nitro-glycerin pure and simple. This view is confirmed by the action of certain dynamites which are so prepared as to explode with exceeding rapidity and which fall very low in the scale. They are evidently so quick as to be unsuited for subaqueous work.

As the result of this branch of his investigation, General Abbot concludes that as regards permanency, power, convenience and readiness in manufacture, dynamite No. 1 is the best explosive for our submarine mines. Hence in studying the destructive effect of subaqueous explosions this compound was exclusively used. In the discussion of the results obtained comparisons were made with those obtained in England, France, Sweden and elsewhere.

As a result of this investigation it is found that if we adopt an instantaneous pressure of 6500 lbs. per square inch as the measure of a fatal shock to a first-class ship-of-war, the following are the extreme destructive ranges of submarine mines :

	Charge, pounds.	Horizontal range, feet.	Vertical range, feet.
Dynamite No. 1	100	16.3	18.6
Gun-cotton	100	14.7	17.3
Explosive gelatine	100	18.2	20.3
Sporting powder, 1 fuse per cubic foot .	100	3.3	3.3
“ “ 1 central fuse . . .	100	3.1	3.1
Dynamite No. 1	200	22.6	25.9
Gun-cotton	200	20.5	24.1
Explosive gelatine	200	25.3	28.2
Sporting powder, 1 fuse per cubic foot .	200	7.4	7.4
“ “ 1 central fuse . . .	200	6.6	6.6

Dynamite No. 1	500	35.0	40.0
Gun-cotton	500	31.7	37.3
Explosive gelatine	500	39.1	43.7
Sporting powder, 1 fuse per cubic foot .	500	19.5	19.5
“ “ 1 central fuse . . .	500	16.2	16.2

The smallness of the additional range obtained by increasing the charge from 200 to 500 lbs. has led to the adoption of the 200-lb. charge for shallow harbors.

The general formula for the extreme destructive range (Δ) of a submarine mine charged with an explosive compound and acting upon a first-class ship-of-war, which has resulted from this investigation and from which the foregoing table has been computed, may be placed under the following form, for convenience of application :

$$\Delta = \frac{\sqrt[2.1]{(\vartheta + E)C}}{8} \text{ in which}$$

Δ = range in feet,

C = the weight of the explosive in pounds,

E = a constant to be determined by experiment. (It is for dynamite 186 and for gun-cotton 135.)

ϑ = the angle with the vertical passing through the centre of the charge, made by a line drawn from that point to the surface exposed to the shock, reckoned from the nadir and expressed in degrees.

If the vessel lies at this or a less distance she will be destroyed ; if at a greater distance she will escape rupture of the hull. A submergence of the charge properly suited to its size is supposed—say not less than three or four feet for one hundred pounds and proportionally greater for larger amounts. By this mode of treatment the results are made general. Suppose, for example, that the strength of the hulls of ships-of-war should be increased. A corresponding change in the constant 8 would indicate the new requirements. Suppose that some new explosive compound should prove to be better suited to the work than dynamite. A new value for the constant E is all the change that would be required. It will therefore be comparatively easy hereafter to keep pace with modern progress.

The remainder of the report is devoted to the investigations of electrical fuses and of the various forms of igniting apparatus, and it is distinguished by the same fullness, accuracy and thoroughness which characterize the portions abstracted. The appendices contain

full details of upwards of 700 explosions, which may be used in any further discussion of this subject.

A new form of dynamite is proposed, in which ninety parts of dynamite or blasting gelatine are mixed with ten per cent. of india rubber in sufficient solvent to dissolve it. The whole is thoroughly stirred and the solvent evaporated; the mixture is then packed in rubber cartridges.—*Jour. Soc. Chem. Ind. and School of Mines Quarterly*, 4, 3, 239, April, 1883.

The School of Mines Quarterly 4, 1, 15th September, 1882, contains a paper by Arthur H. Elliott, F. C. S., "On Nitro-glycerin," which records the solvent action of a large number of substances on nitro-glycerin. In making these experiments it was found impossible to heat nitro-glycerin near the boiling point of water without some of it evaporating. Ammonic sulphhydrate and ferrous chloride both reduced nitro-glycerin when hot. The action of ammoniac sulphhydrate is shown thus:

Two quantities, 3.847 and 3.758 grams of nitro-glycerin were each dissolved in twenty-five cubic centimetres of absolute alcohol, and each was treated with about fifty cubic centimetres of ammoniac sulphhydrate solution (made by saturating ammoniac hydrate, sp. gr. .98, with sulphuretted hydrogen). The solutions became hot, dark colored, and sulphur separated which dissolved again when more ammoniac sulphhydrate was added, much ammonia being given off during the action. The solutions were now evaporated to dryness to expel the excess of ammonia and ammoniac sulphhydrate. The residue containing separated sulphur was treated with water, the solution filtered and the residue washed with water. The filtered solution and washings were now evaporated until the weight was constant. The glycerin so obtained weighed 1.552 and 1.540 grams, which is equal to 40.34 and 40.97 per cent. on the nitro-glycerin taken, while the theoretical figures are 40.52 per cent. Ammonic sulphhydrate, therefore, reduces nitro-glycerin and gives practically the theoretical quantity of glycerin.

In the paper of Prof. H. Debus on the "Chemical Theory of Gunpowder" (*Nav. Inst. Proc.* 9, 1, Mar. 1883), on page 74, he repeats the error concerning the composition of the United States regulation powder which is found in many foreign books. The United States regulation gunpowder is composed of 75 parts of saltpetre, 15 parts of charcoal and 10 parts of sulphur.

From *Census Bulletin*, No. 304, we learn that there were in 1880 in the United States, 39 factories for the manufacture of explosives and fireworks, having a capital of \$579,750, and employing 313 men, 217 women and 205 youths. The wages paid during the year amounted to \$216,069; the value of the materials was \$840,877, and of the products, \$1,391,132. 33 establishments with a capital of \$4,983,560 were devoted to gunpowder; 988 men, 20 women and 3 youths were employed. The wages amounted to \$510,550, the value of the materials to \$2,053,488, and of the products to \$3,348,941. There were 21 factories for the high explosives, with a capital of \$1,605,625. 328 men and 1 woman were employed, and their wages were \$164,864. The value of the material was \$1,218,061, and of the product, \$2,453,088.

Under the title "Dust Explosions in Breweries," C. John Hexamer gives in *Four. Frank. Inst.* [3] 85, 2, 121, February, 1883, an account of the causes of these explosions and the precautions to be taken and devices invented for preventing them. He especially dwells upon the necessity of removing bits of iron from the grain by passing it over a plate magnet; the lining of the elevator with copper, and the use of geared rollers with spring clamps in place of friction rollers.

In the same journal, page 135, in a "Summary of Progress in Science and Industry for 1882," reference is made to the use of caustic lime as a substitute for gunpowder in coal mines. The lime is made into cartridges by a hydraulic pressure of 40 tons. By a simple and inexpensive method these cartridges are confined in the bore holes in such a manner that when a quantity of water is forced into contact with them, the combined effect of the steam generated and the expansion of the lime in slacking breaks the coal out in from 10 to 15 minutes and without wastage from pulverization. The process has been in use now for some time and works well.

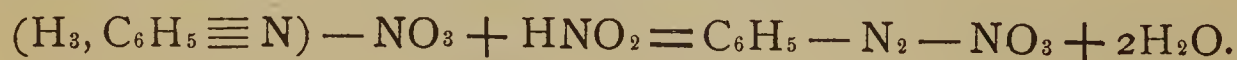
Mem. Soc. Eng. Civ. September, 1882, page 270, gives an interesting and detailed account of the removal of an iron wreck in the channel of the Danube which was dangerous to shipping. 790 kilos of explosive gelatine and 475 kilos of dynamite No. 1 were used, the former costing \$1 per kilo and the latter 64 to 80 cents per kilo in Vienna. The total cost of removal was \$7250, and the work occupied two months.

Dr. C. William Siemens, in his presidential address before the British Association for the Advancement of Science entitled "Science in Relation to the Arts," says that when the Association met at Southampton on a former occasion, Schonbein announced to the world his discovery of gun-cotton. This discovery has led the way to many valuable researches on explosives generally, in which Mr. Abel has taken a leading part. Recent investigations by him in connection with Captain Noble, upon the explosive action of gun-cotton and gunpowder confined in a strong chamber (which have not yet been published), deserve particular attention. They show that while by the method of investigation pursued about twenty years ago by Karolyi (of exploding gunpowder in very small charges in shells confined within a large shell partially exhausted of air) the composition of the gaseous products was found to be complicated and liable to variation, the chemical metamorphosis which gun-cotton sustains, when exploded under conditions such as obtained in its practical application, is simple and very uniform. Among other interesting points noticed in this direction was the fact that, as in the case of gunpowder, the proportion of carbonic acid increases while that of carbonic oxide diminishes with the density of the charge. The explosion of gun-cotton, whether in the form of wool, or in the form of loosely spun thread, or in the packed compressed form devised by Abel, furnished practically the same results if fired under pressure, that is, under strong confinement—the conditions being favorable to the full development of its explosive force; but some marked differences in the composition of the products of metamorphoses were observed where gun-cotton was fired by detonation. With regard to the tension exerted by the products of explosion, some interesting points were observed, which introduce very considerable difficulties into the investigation of the action of fired gun-cotton. Thus, whereas no marked differences are observed in the tension developed by small charges and by very much larger charges of gunpowder having the same density (*i. e.* occupying the same volume relatively to the entire space in which they are exploded), the reverse is the case with respect to gun-cotton. Under similar conditions in regard to density of charge, 100 grams of gun-cotton gave a measured tension of about 20 tons on the square inch, 1500 grams gave a tension of about 29 tons (in several very concordant observations), while a charge of 2.5 kilos gave a pressure of about 45 tons, this being the maximum measured tension obtained with a charge of gunpowder of five times the density of the above.

The extreme violence of the explosion of gun-cotton as compared with gunpowder when fired in a closed space was a feature attended with formidable difficulties. In whatever way the charge was arranged in the firing cylinder, if it had free access to the enclosed crusher gauge, the pressures recorded by the latter were always much greater than when means were taken to prevent the wave of matter suddenly set in motion from acting directly upon the gauge. The abnormal wave pressures recorded at the same time that the general tension in the cylinder was measured, amounted in the experiment to 42.3 tons, where the general tension was recorded at 20 tons; and in another where the pressure was measured at 29 tons, the wave pressure recorded was 44 tons. Measurements of the temperature of explosion of gun-cotton showed it to be about double that of the explosion of gunpowder. One of the effects observed to be produced by this sudden enormous development of heat was the covering of the inner surfaces of the steel explosion-vessel with a network of cracks, small portions of the surface being sometimes actually fractured. The explosion of charges of gun-cotton up to 2.5 kilos in perfectly closed chambers, with development of pressures approaching to 50 tons on the square inch, constitutes alone a perfectly novel feat in investigations of this class. Messrs. Noble and Abel are also continuing their researches upon fired gunpowder, being at present occupied with an inquiry into the influence exerted upon the chemical metamorphosis and ballistic effects of fired gunpowder by variation in its composition, their attention being directed especially to the discovery of the cause of the more or less considerable erosion of the interior surface of guns produced by the exploding charge—an effect which, notwithstanding the application of devices in the building up of the charge specially directed to the preservation of the gun's bore, has become so serious that, with the enormous charges now used in our heavy guns, the erosive action on the surface of the bore produced by a single round is distinctly perceptible. As there appeared to be *prima facie* reasons why the erosive action of powder upon the surface of the bore at the high temperatures developed should be at any rate in part due to its one component sulphur, Noble and Abel have made experiments with powders of usual composition and with others in which the proportion of sulphur was considerably increased, the extent of erosive action of the products escaping from the explosion-vessel under high tension being carefully determined. With small charges a particular powder containing no sulphur was found to exert

very little erosive action as compared with ordinary cannon powder; but another powder containing the maximum proportion of sulphur tried (15 per cent.) was found equal to it under these conditions and exerted very decidedly less erosive action than it, when larger charges were reached. Other important contributions to our knowledge of the action of fired gunpowder in guns, as well as decided improvements in the gunpowder manufactured for the very heavy ordnance of the present day, may be expected to result from a continuance of these investigations. Professor Carl Himly, of Kiel, having been engaged upon investigations of a similar nature, has lately proposed a gunpowder in which hydrocarbons precipitated from solutions in naphtha take the place of the charcoal and sulphur of ordinary powder. This powder has amongst others the peculiar property of completely resisting the action of water, so that the old caution "keep your powder dry," may hereafter be unnecessary.—(*Jour. Frank. Inst.* **115**, 687, 215, March, 1883.)

All of the explosive substances in common use are believed to owe their explosive properties to the fact that they contain nitrogen which exists wholly or in part in the body, united with oxygen, in the form of nitryl NO_2 . There is yet another class of nitrogenized bodies, some of which are explosive, which may be regarded as formed by the replacement of two atoms of hydrogen (in two molecules of an aromatic hydrocarbon) by two atoms of nitrogen. A body so constituted is called an *azo* compound. Diazobenzene $\text{C}_6\text{H}_5 - \text{N} \equiv \text{N} - \text{C}_6\text{H}_5$, which may be formed by the indirect substitution of hydrogen by nitrogen in benzene, is a type of this class. It stands intermediate in composition between nitro-benzene and aniline. Diazobenzene is a quite unstable substance, while the nitrate is a crystalline solid, which is employed in the arts for the manufacture of dye-stuffs, and which is so explosive that it has been proposed for use as a detonating primer. It may be formed by the action of nitrous acid on phenylammonium nitrate according to the reaction



Berthelot and Vieille have recently made a study of the properties of diazobenzene nitrate, *Annales de Chimie et de Physique* [5] **27**, 194, Oct. 1882, and they consider it as representing the residue of two nitrogenized bodies which have lost, the one (nitrous acid) its oxygen, the other (aniline) a part of its hydrogen, in the act of com-

bination; but a notable portion of the energy of these elements remains in the residue, which accounts for its explosive character. They have examined this substance in the same way as they have done for fulminating mercury.* If preserved in dry air out of contact with the light it can be kept for two months and more, but exposed to daylight it slowly changes; in moist air the change is rapid, and in contact with water it is decomposed immediately. It is as sensitive to a blow as mercuric fulminate. On heating it detonates with extreme violence at about 90° , while mercuric fulminate detonates at about 195° . Slowly heated at a lower temperature it slowly decomposes. Its density is 1.37. Total heat of combustion under constant volume $+783.9$ cal. and under constant pressure $+782.9$ cal. Heat of formation -89 cal. showing it to be an endothermic† substance like the other high explosives. The heat of combustion was determined by burning in oxygen; so the heat formed during detonation, pure and simple, was also measured and was found to be $+114.8$ cal. per equivalent or 687.7 cal. per kilo. The volume of the gases produced was 817.8 litres per kilo or 136.6 litres per equivalent consisting of

HCN	3.2	and for 136.6 litres	4.4
CO	48.65		66.4
CH ₄	2.15		2.9
H.	27.7		37.9
N	18.3		25.0
	<hr/>		<hr/>
	100.00		136.6

We notice in the reaction that a considerable quantity of hydrocyanic acid results; that the oxygen all unites to form carbon protoxide, no water being formed; three-fourths of the nitrogen is liberated in the free state, and a fifteenth in the state of hydrocyanic acid. The remainder of the nitrogen is found in the carbonaceous residue, about one-fifth existing as ammonia and the remainder in a peculiar state of combination with the carbon. Of the five equivalents of hydrogen about three and one-half exist free; a half equivalent forms marsh gas, a half ammonia and hydrocyanic acid, and about a half is united with the carbon. One-half the carbon forms carbon protoxide, and a ninth of the remainder exists as marsh gas and hydrocyanic acid. The solid residue contains four-ninths of the carbon. The empirical formula of the residue is $C_5H_2N_2$. It is then a carbon rich in hydro-

* Proc. Nav. Inst., Vol. VIII, p. 441.

† Proc. Nav. Inst., Vol. VIII, p. 305.

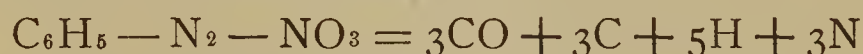
gen and nitrogen probably combined under the form of condensed and polymeric bodies. By calculation the gaseous products contain 75.9 per cent. of the weight of the substance; there remains 24.1 per cent. of residue in the form of a very voluminous black, impalpable powder with an ammoniacal odor. The ammonia in the residue was 00.11 per cent., and in the gas 00.0042 per cent. The following table represents these results in 1000 parts by weight:

Nitrogen	{ free	189.7	} 215.6	} 251.2
	{ as HCN	16.7		
	{ as H ₃ N	9.2		
	{ combined with the carbon		35.6	
Oxygen as CO				287.6
Hydrogen	{ free	20.5	} 26.9	} 29.9
	{ as CH ₄	3.2		
	{ as HCN	1.2		
	{ as H ₃ N	2.0		
{ combined with the carbon			3.0	
Carbon	{ as CO	215.8	} 239.6	} 431.3
	{ as HCN	14.3		
	{ as CH ₂	9.5		
	{ carbon		191.7	

Summary.

Gaseous products	769.7	} .	1000.0
Residue	230.3		

Neglecting the secondary products the reaction may be written



but ammonia, marsh gas and hydrocyanic acid are formed as secondary products.

The simple decomposition in accordance with the above reaction should liberate + 204.7 cal. under constant volume instead of + 114.8 as found. This shows that the secondary products have absorbed - 89.9 cal. during their formation. This absorption results chiefly from the formation of the compound of carbon and nitrogen. The exothermic formation of the ammonia and marsh gas very nearly compensates for the endothermic formation of the hydrocyanic acid. This agrees with the general observation that the hydrocarbons, rich in carbon and carbonaceous matter, retain a notable portion of the energy of the complex bodies from which they are derived. It surpasses in some instances the energy of the elements themselves. This observation, first made by Berthelot on acetylene, is quite

generally applicable to pyrogenous decompositions, and serves to explain the singular conditions under which certain endothermic compounds are formed even at the moment when the heat destroys the organic compound.

It remained to determine the tension in a closed vessel. This was determined by the method used for mercuric fulminate, with the following result :

Density of charge.	Weight of charge, grams.	Pressure in kilos per cm. ²	Pressure with mercuric fulminate.
0.1	2.37	990	480
0.2	4.74	2317	1730
0.3	7.11	4581	2700

The pressures for diazobenzene nitrate are greater than those for mercury fulminate for the same density of charge, but on the contrary mercuric fulminate will develop a much greater pressure (24,000 kilos instead of 7500 kilos) when detonated in its own volume, on account of its greater density. The destructive effects of the two explosives differ, following the density of charge. On contact the effect is much more marked with mercuric fulminate.

The same number of this journal, p. 202, contains an article by Berthelot and Vieille, entitled "Researches on Nitrogen Sulphide." The nitrogen sulphide is formed by the action of sulphur chloride on ammonia, and is obtained in well-defined crystals having the formula of NS corresponding to nitric oxide. The substance is not affected by dry or moist air, and has been several times heated to 50° without change. It detonates under the hammer, but is less sensitive than diazobenzene nitrate or mercuric fulminate. It deflagrates at 207°, but more slowly than mercuric fulminate. The pressures developed by the explosion of nitrogen sulphide are very nearly the same as those obtained for mercuric fulminate with a density of 0.2 and 0.3 of charge. But these relations are somewhat uncertain, and cause the very marked difference which exists in the rapidity of decomposition of the two bodies. On account of this the effects produced by the two bodies used as detonators and in fuses ought to be very different.

NAVAL INSTITUTE, ANNAPOLIS, MD.

OCTOBER, 1883.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY PROF. CHAS. E. MUNROE, U. S. N. A.

No. V.

It is a well-known fact that the intervention of an obstacle in the path of a beam of sound waves causes the formation of a shadow, but owing to the length of the waves the shadow is not so marked as for light. In 1826, Colladon made experiments which proved that sound shadows are more perfectly defined in water than in air. Prof. John Le Conte has extended these observations, which he publishes in the *Am. Jour. Science* [3], **23**, 27, Jan. 1882, under the title "On Sound Shadows in Water."

The experiments were executed in 1874, during the engineering operations incident to the removal of "Rincon Rock," a sandstone reef in the harbor of San Francisco, by means of "surface blasting" with "giant powder" or dynamite. The depth of water on the reef was about fifteen feet at low tide, with an extreme tidal range of about six feet. The "cans" or "cartridges" of "giant powder" used contained each about fifteen pounds of the explosive compound, comprising about seventy-five per cent. of nitro-glycerine.

It was observed that the suddenness of the shock imparted to the water by this explosive agent produced the most remarkable and astonishing effects. At the distance of 300 feet or more from the detonating cartridge, two distinct shocks were experienced. The first shock came through the intervening waters, and was felt as a short concussion or click before there was any sensible elevation of the

* As it is proposed to continue these notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars.

column of water resting over the point of explosion. The second shock came a little later by the air and was heard. It was evidently communicated to the air by the water, at the time the elastic pulse transmitted by this liquid (the first shock) emerged, in a direction nearly normal to its surface, over a limited area around a point vertically above the exploding cartridge. This was obvious from the fact that aerial sound came from this region. The area, which was the source of the sound transmitted by the air, was the same as that from which the small jets of water (noticed hereafter) were projected. The gases generated during the explosion came to the surface much later than this shock, and after elevating the column of water, over the position of the cartridge, to the height of twenty-five or thirty feet. It is the character of the first shock that deserves special notice. To a person sitting in a small boat floating on the water at a distance of 300 feet or more from the point of explosion, with his feet resting on its bottom, the shock was felt as a sudden blow applied to the soles of the feet. In fact, it drove out the oakum from the seams in the bottom of the boat. When the observer stood on the top of a vertical wooden pile, this shock was felt as a concussion coming up from the water along the cylinder of wood. The concussion produced by such an explosion was so violent that it killed or stunned the fish in the water within a radius of 200 or 300 feet from the explosive centre. They rose to the surface in a helpless condition, and were easily secured.

In these experiments the observer stood on the top of a vertical, cylindrical pile (the trunk of an Oregon pine) about one foot in diameter, situated about forty feet horizontally from the explosive cartridge. A bottle being secured to a rigid rod, was first plunged under the water from ten to twelve inches behind the pile, that is, within its geometrical shadow. The shock of the explosion did not injure the bottle. It was then plunged into the water in front of the pile, or outside its geometrical shadow. In this position the bottle was shivered to atoms by the concussion due to the explosion. The experiments were varied by plunging bottles into the water in various positions around the pile within and outside of its geometrical projections from the explosive centre; and in all cases they were protected from injury when within the geometrical shadow, and were shivered when outside of the same. The same results took place whether the bottles were filled with water or with air. The breaking of a glass vessel by a sudden shock communicated by means of water is a fact

long known, and is illustrated by the old familiar class experiment of exploding a "Prince Rupert drop" while its bulb is plunged into an ordinary phial filled with water.

Cylindrical glass tubes about six feet long and one-fifth inch in diameter, the glass being about 0.5 of an inch in thickness, were also employed. They were covered by pasting cartridge paper over them, so as to prevent the loss of fragments when breakage occurred. The tubes were adjusted to a framework of wood, so arranged that they could be plunged in a horizontal position beneath the surface of the water behind the pile, the axis of the tube being at right angles to the plane of its shadow, and held there (the observer standing as before on the top) with the middle of the tube in the geometrical shadow, while the extremities projected on either side about 2.5 feet beyond the boundaries of said shadow. In every case the shock of the explosion shivered the projecting portions of the tube, and left the portion within the shadow uninjured. The boundaries between the broken and the protected portions of the glass were sharply defined. By standing on the top of a second pile in the direction of the axis of the shadow of the first pile, and distant about 12 feet, the experiments were varied by plunging the framework and tubes—adjusted at right angles to the plane of the prolonged shadow—into the water at this distance (12 feet) from the obstacle which obstructed the sound-wave transmitted by the liquid. The shock of the explosion produced sensibly the same results as when the tube was near to the obstructing obstacle: the protected portion of the horizontal glass tube was sensibly equal in length to the diameter of the pile casting the shadow. Hence the shadow of the cylindrical pile extended back for about 12 feet between sensibly parallel vertical planes, and its boundaries at this distance were still sharply defined. It is evident that, if the explosive centre were of insensible magnitude, the horizontal thickness of the geometrical shadow of the pile, at a distance of twelve feet beyond it, would be augmented in the ratio of 40 to $40 + 12$, or of 40 to 52, these numbers being the distances in feet from the centre. So that if the thickness of the shadow at the pile were 12 inches, its thickness at 12 feet beyond would be 15.6 inches. If, however, the explosive energy occupied more or less space (as was the case in relation to the "giant powder" cartridges), the thickness of the geometrical shadow or umbra cast by the pile might not increase sensibly with augmenting distance, and, indeed, in case the exploding body exceeded 12 inches in diameter the thick-

ness of the shadow would diminish with increasing distance from the obstructing pile ; as in the case of the umbra cast by an opaque body which is smaller than the luminous source. Another interesting phenomenon came under notice during the execution of these experiments. It was the singular effects observed on the surface of the water (when perfectly calm and glassy) for a certain area around the point immediately over the exploding cartridge. Simultaneous with the first shock transmitted by the water—and before the ascending gases of explosion disturbed it—the surface of the liquid exhibited numerous jets of water, rising to the height of about 3 inches over the centre of the area, and diminishing in height with augmenting distance from the centre. The appearance presented was not unlike that produced by a heavy shower of rain falling on the calm waters of a lake. To an observer in a boat floating on the adjacent water, and consequently viewing the phenomenon from a point near the water-level, there seemed to be a curious quincunx-like arrangement of the jets.

In the case of solitary waves generated by sudden blows and explosions, it is more difficult to form a just estimate of the wave-length than in the case of musical sounds. Nevertheless it is evident that the wave-length must be directly proportional to the time occupied by the displacing impulse multiplied by the velocity of transmission of the elastic pulse. If L = wave-length, t = time of the generating impulse, and v = velocity of sound in the elastic medium, we have L varies as $t \times v$ or $L = t \times v$. Consequently, in a given medium in which v remains constant, L will be a function of t , or the duration of the generative impulse ; so that when the factor t is indefinitely small, the value L will be correspondingly small. Hence, when the time of the blow or explosive impulse is exceedingly brief, the wave-length must be proportionately short.

All the phenomena incident to the explosion or detonation of the nitro-glycerine compounds indicate that the impulse generated is of indefinitely brief duration ; indeed, its suddenness is almost beyond conception. The efficiency of surface blasting under water by means of these explosive compounds depends upon this extraordinary suddenness of detonation, which renders the effect akin to that of the sudden blow of an enormous unyielding mass. It is evident that the wave generated in an elastic medium like water by an explosion of this character must be very intense and very short. Hence the acoustical shadow produced by an obstacle placed in its path of propagation must,

as in the case of light, be sharply defined and definite in its boundaries. Thus, the striking fact that the protecting influence of the piles on the glass vessels plunged in the water was narrowly circumscribed within the limits of the geometrical shadow may be rationally traced to the extreme shortness of the elastic waves, due to the inconceivably brief duration of action of the generative detonations. If the foregoing is the true explanation of the definiteness of the sound shadows cast in the preceding experiments, then the waves generated by the explosion of ordinary gunpowder, being less sudden, should not produce as sharply defined shadows as those due to the detonation of dynamite. We have, so far as known, no specific experiments testing this point, but it seems to be quite reasonable that such will be found to be the case whenever the test of experiment is applied. For it is well known that the subaqueous explosion of ordinary powder does not give rise to the remarkable concussions so characteristic of the detonations of the nitro-glycerine mixtures. Moreover, if this explanation is correct, the acoustical shadows produced by nitro-glycerine detonations in air ought also to be more sharply defined than those due to sounds less suddenly generated. In other words, if the distinctness of sound shadows depends upon the duration of the impulse which produces the accompanying sound wave, then the definiteness of the shadows cast by sounds propagated through the air should vary with the suddenness of the action of the generating cause.

Inasmuch as the variations in the duration of the genesis of audible sounds in the atmosphere must in ordinary experience be very great, it may at first sight appear incredible that the corresponding differences in the perfection of sound shadows cast by obstacles in the paths of different kinds of sounds should have escaped the most casual observation. But it must be recollected that, for the reasons already assigned, aerial acoustical shadows are not readily appreciated by the ear. Moreover, in the case of sounds transmitted by the air, the distinctness of such shadows is most seriously impaired by the numerous reflected waves which come from circumjacent objects. It should be borne in mind that it is only very recently that the influence of acuteness of sounds on the distinctness of the resulting shadows has been very satisfactorily verified by experiment. In like manner, I venture to predict that careful experiments will verify the deduction that the shadows due to sounds generated by the extraordinarily brief detonations of dynamite are more sharply defined than those

owing their origin to sounds less suddenly produced. In confirmation of the foregoing view the following observation may be cited: On the 16th of April, 1880, an explosion of about 2000 or 3000 pounds of a nitro-glycerine compound occurred at the "Giant Powder Works," situated under a bluff on the eastern shore of the bay of San Francisco, at a distance (determined by triangulation) of 16,201 feet (4938 meters) in a direct line in a northwest direction from my room in the University building. About twenty-five men were blown to atoms; no one escaping to reveal the cause of the accident. The concussion at the University buildings (more than three miles distant) was sufficient to break about a dozen panes of stout glass on the side next to the explosive centre. Nearly every person about the University grounds experienced two distinct shocks; one transmitted by the air, and the other by the ground. The cottage occupied by my brother was situated in the geometrical shadow of one of the buildings; being about 890 feet on the farther side of it. No aerial shock was experienced by him or any member of the household; and the concussion transmitted by the earth was alone felt as a shock emanating from the floor. In other terms, the acoustical shadows cast by the intervening structure completely cut off the sound-wave coming by the air. It is scarcely necessary to add that for ordinary sounds such would not have been the result. The singular phenomenon observed of numerous small jets projected from the surface of the water when the shock transmitted by the liquid reached the surface area above the exploded cartridge, was probably due to the circumstance that when the short and intense electric wave emerged in a direction normal, or nearly normal, to the aqueous surface, the tense superficial capillary film yielded to the sudden impulse more readily at some points than others. The sensibly homogeneous character of such a tensile elastic film would naturally tend to group the points of rupture, or jets of water, into more or less perfect order, partaking more or less of geometrical symmetry. Hence the curious quincunx-like arrangement of jets as viewed by the observer near the water-level. According to this view the phenomenon in question seems to find its counterpart or analogue in the more or less symmetrical forms produced by the intersection of the lines of rupture, as the result of tensional strains due to the contraction of homogeneous masses during the process of cooling or of desiccation.

Thus the columnar structure of certain igneous rocks seems to be due to the tensile stress of contractions by cooling after solidification

supervened ; while the analogous structure developed by the desiccation of homogeneous masses of moist clay, mud or starch, appears to be produced by a similar strain consequent upon shrinkage from loss of moisture. In a similar manner the tense superficial capillary film of the water when it experiences the sudden molecular impulse due to the emergence of the elastic pulse, is ruptured along lines more or less symmetrically disposed on the surface of the water ; and the liquid beneath is projected through these lines or points of least resistance.

In connection with the foregoing the observations of Gen. Abbot (*Report on Submarine Mines*, p. 41) may prove interesting. Thus he states that :

“Before proceeding to discuss mathematically the action of the forces developed by explosions under water, a brief abstract will be given of notes relating to what is usually heard, felt and seen in the vicinity. The sound is deadened to a surprising degree by water over the charge. A large torpedo exploded 10 feet or more below the surface gives a dull muffled report that often is hardly noticed by one intently watching the jet. When the water covering is so thin as to allow the gas instantly to escape into the air, the sound is far more intense. Thus one pound of dynamite exploded three feet below the surface produces locally a much louder sound than 500 pounds submerged 20 feet. It is a general characteristic of small and deeply submerged charges of the explosive compounds, and of some quick acting explosive mixtures as well, that at the instant of detonation, before any disturbance of the water at the surface is visible, three sharp sounds are heard resembling raps upon a hard substance. They are of nearly equal intensity ; but the interval of time between the first and the second appears to be longer than between the second and the third. That these repetitions are not simply echoes, and that there are really more than three of the impulses, although the ear hardly detects a greater number, have been conclusively proved in several instances where a gauge clutch happened to be out of order. In such cases several successive indentations in the bottom of the lead have been made by the centre pin as the cylinder moved laterally under the upward jerk given by the buoy. Successive impulses may also be distinctly felt by one standing in a boat near the explosion ; and if the hand be placed in the water, sensations resembling electric shocks are experienced. The influence of the shock upon fish is

noteworthy. In the immediate vicinity, even of small charges, death appears to be instantaneous. At a greater distance the air bladder is ruptured, and the air ballast escaping into the abdomen, the fish floats upon its back at the surface, although still able to swim with considerable speed. At still longer ranges the effect appears to be momentary, simply causing an upward dart into the air. Even five pounds of dynamite will produce this effect upon a shoal of menhaden at distances of several hundred yards, showing that the nervous system of that fish is one of the most sensitive of known gauges.

The jet, as well as the sound, is greatly influenced by the submergence. As small charges afford the best opportunity for studying this phenomenon in detail, the following summary of many records upon explosive compounds is given. A charge of one-fourth of a pound submerged about 35 feet occasions no marked disturbance at the surface, but bubbles of gas continue to rise for many seconds. Fish at 100 yards distance often leap into the air. A half-pound charge detonated 6 feet below the surface produces a sharp report, and throws up a jet from 20 to 30 feet into the air. With a one pound charge submerged 35 feet, the buoy supporting the ring instantly rises about 2 feet and sinks back out of sight. An upward, boiling motion of the water begins about 12 seconds after the explosion. In a strong current this may appear several feet away from the buoy. When the charge is submerged 25 feet the boil rises quicker, and the buoy often re-appears with it. With a two pound charge submerged 35 feet the phenomena are similar, the boil appearing in about 9 seconds. With a 3 pound charge at the same depth the upward current of water assumes the appearance of a small dome at the surface, appearing about 5 seconds after the explosion. The buoy rises 4 or 5 feet instantly, and sinks back out of sight. As the charge is increased to 5, 8 and 10 pounds, the depth remaining the same, the greater intensity of action is shown by a quicker motion of the buoy, which is also surrounded by a mist thrown upward from the surface. The dome appears in a second or two, and expands into a small white jet of water 8 or 10 feet high. A boat 50 feet distant from the buoy receives a jar sufficient to lift small articles. Fishes of the herring family dart into the air as far off as the eye can conveniently distinguish them, those within a radius of a couple of hundred feet being crippled by the concussion. With explosive mixtures the effects are similar but less intense. For example, 25 pounds of mortar powder, fired 35 feet below the surface, cause a misty shower to rise

a foot or two above the water ; the buoy shoots up to its full length and falls upon its side ; then a white dome rises around it about 10 feet high. When a strong iron case is used, three sharp raps are heard, which are not often noticed with a wooden case. When 50 pounds of mortar powder are fired 5 feet below the surface, the jet is about 170 feet high ; at 16 feet it is about 40 feet high ; at 35 feet it is 20 to 30 feet high ; and at 68 feet there is simply a large upward boil around the buoy, occurring several seconds after the explosion. In deep explosions the buoy always shoots upward, and often subsides before any disturbance is seen at the surface.

The *Bulletins de l'Académie Royale de Belgique* contain an extract of a work upon *experimental ballistics*, by M. Melsens, in which the learned writer propounds a remarkable theory in regard to the action of the air existing in front of projectiles, and which forms one with the solid projectile during the greater part of its course.

M. Melsens describes one of the various contrivances he made use of for receiving the air in front of a projectile moving at a great speed ; it consists practically in firing a bullet in a trunconical aperture made in a solid block of steel or cast-iron ; at the extreme end of the cone, towards the summit, the aperture of the cone may be several millimetres in diameter ; it is made to communicate with iron tubes previously filled with water, which extend into a pneumatic trough containing a bell for the reception of the air.

When a spherical leaden ball enters the cone, which is constructed so as to prevent the outflow of the water, the air in front of it is driven forward ; a portion of the ball enters the orifice of the cone, and the remainder, being wedged in it, forms an obstruction and prevents the escape of the water. The part in the cone often terminates in a perfect point, very sharp and tapering ; sometimes a characteristic stricture is observed which recalls what has been named in liquids *the contraction of the vein*. Bullets are seen in which this bulging out forward is ready to separate. Detached and isolated drops are found in the tube, as if the solid lead had flowed like a liquid.

M. Melsens' experiments differ from those of M. Tresca, in the fact that while in the former we find drops that are entirely free and every stage of whose formations we can to a certain extent follow, in the latter the flowing of the solid lead, under high pressure, causes the converging motions of the molecules pressing on all sides towards the orifice to yield to the pressures which, spreading from the upper part

of the block, extend throughout the whole mass, determining what in liquids has been termed the contraction of the vein.

Upon the subject of the resistance of air in gun-barrels, Prof. Colladon has addressed to M. Melsens a letter containing some curious and little-known facts, which we think useful to reproduce *in extenso* :

My honored colleague : Your work on experimental ballistics, and the interesting phenomena which you have discovered and described in the paper you sent me, determined me to communicate to you an old experiment which I have often repeated, either before my scholars at the *Ecole Centrale des Arts et Manufactures*, in Paris, or later, during my course of instruction in the scientific branch, at the Academy of Geneva.

The Swiss carbines used in target practice about 60 years ago were pretty heavy pieces ; the barrels, generally very thick, were longer than those of modern rifles ; besides, at that time, they used spherical balls. There are examples of target-shooters who, on a wager, loaded their carbine with a round ball, grasped firmly the extremity of the barrel, closed the muzzle with their thumb, and fired their piece without the thumb being injured, which presupposes a rare strength in the wrist and muscles.

Having been intrusted with the instruction in theoretical and applied mechanics, at the *Ecole Centrale des Arts et Manufactures de Paris*, in 1830, shortly after the formation of that Institution, I introduced in the course of my lectures a great many new experiments, and set in motion before my scholars apparatus or pieces of machinery borrowed from private parties. Among other experiments, I used to repeat every year, as I did later, at the Academy of Geneva, an experiment recalling that which I communicated to you.

I loaded heavily, by means of compressed air, the hollow iron breech of an air-gun, then screwing down the barrel, I introduced in it a round leaden ball, moving freely, but with a diameter very little less than that of the bore of the gun. Placing then the air-gun in an upright position, with the stock resting on the floor, I grasped firmly the extremity of the barrel, and pressing tightly my thumb over the muzzle, I ordered my assistant to pull the trigger ; my thumb remained undisturbed and the ball was heard falling back in the barrel. After this, without any additional charge and with the same ball, in the presence of the audience, I fired at a deal-board from one to one-and-a-half centimetre thick, and the plank was pierced through ;

generally my assistant, who had implicit trust in my aim, held in his hand the small board, or a piece of glass in which the bullet made a pretty clear hole with but very few cracks.

The experiment, I repeat, is without any danger to the operator, if he can trust to his muscles, if the barrel is more than 80 centimetres long, if the ball is spherical, and if its diameter differs very little from that of the bore, for this ball must act as a piston, and its whole energy must be exclusively employed in compressing the air whose egress is prevented by the thumb.

I presume it would be dangerous to load the gun with a bullet of too small a diameter, or with small shot. It is hardly necessary to add that the least instability in the vigorous pressure of the thumb, or in the impervious closing of the bore, would cause the bullet to hit and probably to seriously hurt the extremity of the thumb; it also seems to me that a conical bullet would prove more dangerous than a spherical one, for, according to the power of the charge and the length of the barrel, the bullet must come very close to the thumb before its energy is spent in the act of compression. At any rate, we would dread the burning of the skin of that part of the thumb closing the orifice, for this is an experiment in every way analogous to that of the pneumatic tinder-box, when compressed with great force; doubtless, the time is too short for any serious harm being done. I have repeated the experiment more than a score of times without any injury, either from shock or heat.

DANIEL COLLADON.

GENEVA, *May* 31, 1882.

M. Melsens, in publishing this letter, says, that on communicating the very curious facts contained in it to several artillery officers, otherwise very learned and quite familiar with subjects on ballistics, they professed entire ignorance of them. (*Mem. Soc. Ing. Civ.*, p. 190, August, 1882.)

Several rifle barrels having been swollen and burst, a board of officers were appointed, June 12, 1882, to report upon them, and especially as to the cause of their being swollen at the muzzle. On meeting at Springfield, Mass., the board proceeded to examine the records of the post, and also considered the results of experiments made by direction of the commanding officer.

They find that in September, 1879 (*Ordnance Notes*, No. 117), the

following experiments were made by Captain Greer, Ordnance Department, as indicated by his report as follows: "Two condemned barrels were taken at random from a lot turned in from the field. Eight or ten rounds were fired from each of them, rags of various sizes having been inserted in the bore, a little below the front sight, without affecting the barrel the slightest. Sand next having been inserted in the muzzle, the barrel was shaken so as to remove all but a few grains which adhered to the fouling; the piece was then fired. This was repeated several times without swelling the muzzle. The barrel was then run into wet sand, and the bore nearly filled for about an inch and a half. After firing in this condition the barrel was found swelled at the muzzle precisely like those that have been received from time to time from the field. Several pine plugs from six to eight inches in length were then prepared of a size to fit the bore closely. The second barrel was fired twice with the plugs driven in dry, about one-half their length, twice driven in wet, and twice driven in dry but afterwards swelled by steam, both inside and outside, without injury to the barrel. The inclosed air probably forced the plugs out before the bullets reached them. A plug was then split in two to represent a broken tampion, the air being free to pass by the plug. It was thought the bullet might wedge on the remaining side of the plug, but the barrel was found uninjured after the shot was fired. Occasionally a cup anvil of the Frankford service shell has been found in the barrel after firing. It was thought possible that one of these might become wedged in the barrel and cause the swelling. To test this question an anvil was driven down squarely across the barrel just opposite the front sight. The piece was then fired without injury to the barrel. A second anvil was driven down to the same position, but obliquely to the axis of the bore. No damage resulted from the firing. A long wad of cotton waste was then wet and rolled into a spiral and forced down the barrel several inches by the ramrod. The piece was then fired, when the barrel was found swelled a little beyond the wad, which was probably carried forward a few inches before the bullet wedged upon it." Recently the following experiments were made by direction of Colonel Buffington. A barrel received from the field with a swollen muzzle was cut off back of the swell. The muzzle was then pushed into wet sand and the gun discharged, using the service cartridge, resulting in a swollen muzzle. A second similar gun barrel was taken, the swollen muzzle cut off, the gun fired, the end thrust into dry sand and fired

again, with no perceptible swelling ; it was then fired twice more with the consequent increase of fouling, the muzzle end rested in dry sand just as might easily happen at target practice from carelessness ; then it was fired again and the muzzle found to be swollen. From these experiments it is evident that an obstruction in the bore, particularly sand, will cause a swelling of the barrel. That men frequently lay their guns down or stand with the muzzle resting in the sand no one will probably deny. Such action is liable to pick up sand in the muzzle, particularly after the gun has been fired, resulting in swelling the barrel after firing again. The swelling never takes place from firing a service cartridge when there is no obstruction in the bore. (*Ordnance Notes, U. S. A.*, No. 238.)

The new six-inch breech-loading steel rifle has recently been tried by Lieutenant-Commander Folger, U. S. N., at the Naval Experimental Battery ; and with a charge of 32 pounds, and a projectile weighing 68 pounds, a muzzle velocity of 2130 feet per second was obtained, while the pressure was but 30,720 pounds per sq. inch. Considering the conditions of chamber-space (920 cub. inch), length of bore and weight of projectile, the results are unsurpassed by any hitherto obtained abroad. (*Science*, **I**, 291, April 13, 1883.)

The *Revue Scientifique*, **28**, 769, December 17, 1882 ; **29**, 75, January 21, 1882, and 109, January 28, 1882, contains an exceedingly important article by Berthelot, on "Explosives," in which he reviews the work recently done, and states his present belief as to the cause and character of explosive phenomena and the properties of explosive substances. In the discussion of explosions by influence, he takes exception to the theory of *synchronous vibrations* proposed by Abel* and apparently supported by the experiments of Champion and Pellet, and offers a new theory of his own, which we shall treat of at length later. His method of accounting for the change brought about in the explosive power of gum dynamite, gun cotton and the like, by admixture of inert substances, is interesting. He holds that the camphor modifies the cohesion of the mass of the substance. The substance thus acquires a certain elasticity and solidity, in consequence of which the initial shock of a detonator propagates itself at the start through a much greater mass of the substance than it would if the camphor were not present. A portion of the energy

* *Proc. Nav. Inst.* **4**, 31.

is expended in rending the mass, while some of it is converted into heat; but this heat is dispersed through a greater mass, hence a sudden and local elevation of temperature capable of inducing chemical and mechanical action, cannot be produced but with difficulty, and hence a greater weight of the detonating substance is required where camphor is present. Camphor, however, according to the theory, does not exert any influence on discontinuous powders, and this is shown in practice with potassium chlorate powders. This theory of discontinuity is also illustrated by the statement "that frozen dynamite jelly possesses a sensibility to shock comparable to that of nitro-glycerine if the solidity of the parts has become destroyed by crystallization."

This work of Berthelot's has been translated by M. Benjamin, and published in *Van Nostrand's Engineering Magazine*, 29, 100, August, 1883, but it is rarely that we have met with such wretched, slovenly and unreliable literary work, and it is an added injustice to the eminent author that no reference is made to the source from which the original is drawn. It is only justice to the translator to say, that as he had no opportunity for revising the proof-sheets he cannot be held responsible for the condition of his article. As this is a work with which all students of explosives must become familiar, and as few of them may meet with it in the original, they will be pleased to hear that the article is to be revised and published in a permanent and convenient form, together with a Bibliography of Explosives, in *Van Nostrand's Science Series*.

The same number of *Van Nostrand's Engineering*, p. 125, contains a bright and entertaining article entitled "Who Discovered Gunpowder?" being a translation by Lieutenant John P. Wisser, from the German of Karl Braun, *Nord und Süd*, June, 1883. The article goes to show that the knowledge of gunpowder was brought to Augsburg in 1353 by a Jew named Tysiles, and that from Augsburg, the preparation of gunpowder, its application to military purposes, and the manufacture of firearms, spread throughout Germany and over the rest of Europe. It is conjectured that this Tysiles came from the Orient, and brought thence a knowledge of Greek fire into the free imperial city of Augsburg. Thus is the story of Berthold Schwarz, the Freiburg monk, relegated to the realm of fiction.

In the *Précis and Translations of the Royal Artil. Inst.*, April, '83, is a translation by Captain J. C. Dalton, R. A., from *Memorial*

d'Artilleria, April, '82, on the Portuguese army, from which we learn that the powder factory is at Barcasena, $8\frac{3}{4}$ miles from Lisbon, where the powder is made for the old guns; that for the Krupp guns is procured in Germany. The different classes of powder made at Barcasena have the following compositions:

Class of Powder.	Mark.	Composition.		
		Saltpetre.	Sulphur.	Charcoal.
Mining powder,	MM	62	18	20
Gunpowder, fine grain,	P. F.	76	10	14
“ No. 1, extra fine,	P. S. F. N. 1	76	10	14
“ No. 2,	P. S. F. N. 2	76	10	14
“ large grain,	S	75	12.5	12.5
“ small grain,	FF	75	12.5	12.5
“ rifle,	FN	76	10	14
“ shell,	FNC	76	10	14

They have also tried a powder to take the place of the German powder, and in the experiments made with the 9 cm. gun they obtained with the 33 lb. charge of the same powder an initial velocity of 1512 f. s. The Laboratory is at Braço de Rata, $4\frac{1}{2}$ miles from Lisbon.

H. Güttler proposes to make cartridges of compressed blasting powder by cementing the grains together with dextrine. For this purpose he uses a brown-red charcoal made from resin-free wood at a temperature of 270° – 310° C. and which he claims has the formula $C_8H_4O_2$. The mixture of charcoal, sulphur and nitre is incorporated with the solution of dextrine, corned in grains of 1–2 mm. and after drying pressed into perforated cylinders. These cylinders are dried and shellacked. The reaction on explosion is represented by the equation

$$C_8H_4O_2 + 8KNO_3 + 4S = 8CO_2 + 2H_2O + 8N + 2K_2SO_4 + 2K_2S$$

when potash nitre is used. When soda nitre is employed the reaction is similar, but Na takes the place of K. (*Chemisch-technisches Repertorium*, p. 154, 1883.)

The output of the Spanish Powder Mill at Murcia* for the year 1880–1881 was 102,860 kilos of powder. Of this 16,084 kilos were prismatic powder with seven canals.† While this was as good as the

* Proc. Nav. Inst. 8, 673.

† *Ibid.* 8, 463.

English or German powders, it was much cheaper, since it cost but from forty-eight to fifty cents per kilo. (*Mitt. Artill. u. Genie-Wesens*, 1883. *Kleine Notz*, 19.)

Under the title "Lecture Experiments with Zinc-dust and Sulphur," H. Schwarz calls attention to the vigorous action which attends their union. Ordinarily a mixture of fine iron or fine copper and sulphur is used for showing the phenomena attending chemical union. Schwarz tried zinc-dust and sulphur, and to his surprise his crucible blew up. Experimenting further, he found that a mixture of the substances in atomic proportions is the most useful. This he obtains by passing a mixture of two parts of zinc and one part of sulphur through a sieve. This may be readily ignited by a match, when it burns like gunpowder, with a vivid, brilliant flame, somewhat greenish in color, and leaving only a slight yellowish-white residue of zinc sulphide. It may also be exploded by the blow of a hammer. When tried in a small testing-mortar, two grams of the zinc and sulphur mixture were found to produce the same effect as one-half a gram of gunpowder. (*Ber. Berl. Chem. Ges.* **15**, 15, 2505, Nov. 13, 1882.)

Prof. C. L. Bloxam publishes an article under the title "Reconversion of Nitro-Glycerine into Glycerine," *Chem. News*, **47**, 169, April 13, 1883. He states that the following experiments on this subject appear to possess some interest at the present moment :

1. Nitro-glycerine was shaken with methylated alcohol, which dissolves it readily, and the solution was mixed with an alcoholic solution of KHS (prepared by dissolving KHO in methylated spirit and saturating with H_2S gas). Considerable rise of temperature took place, the liquid became red, a large quantity of sulphur separated, and the nitro-glycerine was entirely decomposed.

2. Nitro-glycerine was shaken with a strong aqueous solution of commercial K_2S . The same changes were observed as in 1, but the rise in temperature was not so great, and the liquid became opaque very suddenly when the decomposition of the nitro-glycerine was completed.

3. The ordinary yellow solution of ammonium sulphide used in the laboratory had the same effect as the K_2S . In this case the mixture was evaporated to dryness on the steam-bath, when bubbles of gas were evolved, due to the decomposition of the ammonium nitrite. The pasty mass of sulphur was treated with alcohol, which extracted the glycerine, subsequently recovered by evaporation. Another por-

tion of the mixture of nitro-glycerine with ammonium sulphide was treated with excess of PbCO_3 and a little lead acetate, filtered, and the ammonium nitrite detected in the solution. The qualitative results would be expressed by the equation $\text{C}_3\text{H}_5(\text{NO}_3)_3 + 3\text{NH}_4\text{HS} = \text{C}_3\text{H}_5(\text{OH})_3 + 3\text{NH}_4\text{NO}_2 + \text{S}_3$, which is similar to that for the action of potassium hydrosulphide upon gun-cotton.

4. Flowers of sulphur and slaked lime were boiled with water till a bright orange solution was obtained. This was filtered, and some nitro-glycerine poured into it. The reduction took place much more slowly than in the other cases, and more agitation was required, because the nitro-glycerine became coated with sulphur. In a few minutes, the reduction appearing to be complete, the separated sulphur was filtered off; the filtrate was clear, and the sulphur bore hammering without the slightest indication of nitro-glycerine.

This would be the cheapest method of decomposing nitro-glycerine. Perhaps the calcium sulphide of tank-waste, obtainable from the alkali works, might answer the purpose.

The reducing action of alkaline sulphides on nitro-glycerine has been pointed out some time since,* and its quantitative application is previously mentioned in these notes.†

On page 448, Vol. VIII, an account is given of the experiments of Mr. Volney and Dr. Henry Morton on the separation of nitro-glycerine from nitrosaccharose. Mr. R. S. Penniman, of the Atlantic Dynamite Works, writes that "as I first suggested and performed the experiment described in 'Notes' No. 2, for the separation of nitro-glycerine from nitro-sugar by the distillation of the nitro-glycerine, I may be permitted to state that this method is not absolutely accurate in its determination of amount of nitro-sugar present, for the reason that the nitro-sugar is also slowly volatile at this temperature, 250°F. , and some is driven off with the nitro-glycerine."

S. H. Hinde proposes a new explosive mixture composed of 64 parts of nitro-glycerine, 12 of ammonium citrate, 0.25 of ethyl palmitate, 0.25 of calcium carbonate, 23 of coal and 0.50 of sodium carbonate. (*Chemisch-technisches Repertorium*, p. 153, 1883.)

"Pyronome" is the name given to a new explosive mixture by M. Sandoy, consisting of 69 parts of saltpetre, 9 of sulphur, 10 of

* Mowbray, 3d Ed., 1874, p. 58. W. N. Hill, Rept. Secy. Navy, 1876, p. 168.

† Nav. Inst. Proc. 9, 294.

charcoal, 8 of metallic antimony, 5 of potassium chlorate, 4 of rye flour and a few centigrams of potassium chromate. These are to be mixed in an equal volume of boiling water and the mass evaporated down to a paste, dried and powdered as wanted. This mixture is said to be cheaper than dynamite, but its manufacture and use must be attended with considerable danger. (*Chem.-tech. Repertorium*, p. 154, 1883. *Boston Journal of Chemistry*, 16, 16, Feb. 1882.)

B. G. & F. L. Benedict have proposed the following mixture for use in primers to replace fulminating mercury: Amorphous phosphorus, 2 parts; minium, 8 parts; potassium chlorate, 2 parts. The oxides of mercury or manganese may be used in the place of the minium. (*Chemisch-technisches Repertorium*, p. 153, 1883.) This differs but little from the caps which caused the explosion in the Rue Beranger, Paris, May 14, 1878. Of these the kind called "single" consisted of

Potassium chlorate,	12 parts.
Amorphous phosphorus,	6 "
Lead oxide,	12 "
Resin,	1 "

while the "double" were composed of

Potassium chlorate,	9 parts.
Amorphous phosphorus,	1 "
Antimony sulphide,	1 "
Sulphur, sublimed,	0.25 "
Nitre,	0.25 "

(*Revue Scientifique*, 29, 80, Jan. 21, 80, 1882.)

A new explosive* has just been patented in England by Dr. C. W. Siemens. The compound is a mixture of saltpetre, chlorate of potash and a solid hydrocarbon, and is suitable both for mining purposes and firearms, while, if ignited in the open air, the combustion takes place slowly and imperfectly, and therefore without danger. The incorporation of the ingredients is by preference effected as follows: The saltpetre, chlorate of potash and hydrocarbon (for which may be taken paraffin, asphaltum, pitch, caoutchouc, gutta-percha, etc.) are mixed together in pulverulent form by passing through sieves or otherwise, and the mixture is then treated with a liquid volatile hydro-

* Nav. Inst. Proc. 9, 298.

carbon, which acts as a solvent to the solid hydrocarbon. A plastic mass is thus produced, which is then formed into cakes or sheets by passing through rollers or otherwise, and is rendered hard by evaporating the liquid solvent used, the sheets or cakes so produced being then converted into grains or pieces of any desired size, in the same manner as ordinary gunpowder. The new compound, which has about the same density as ordinary gunpowder, and is very hard, possesses with equal volume more than double the explosive force of the latter. The intensity of explosion can be regulated at will by varying the proportions of the ingredients and the size of the granules. These proportions should, generally speaking, be such that for each volume of the hydrocarbon, when converted into a gaseous state, there shall be present in the other ingredients three volumes of oxygen. (*Wash. Sunday Herald*, Jan. 14, 1883.)

On page 455, Vol. VIII, Proc. Naval Institute, reference was made to the fact that the British Dynamite Company are now using iron tanks for transportation of their sulphuric acid in the place of the fragile glass carboys formerly used. In a paper on "The Appointment of a U. S. Commission of Tests of Metals," *Trans. Am. Socy. Mechanical Eng.*, 1882, p. 8, Dr. Thomas Egleston points out that instead of the general belief, that the presence of sulphur and phosphorus in iron is always objectionable, being true, it is on the contrary found that for certain uses it is highly desirable, and that among others it has been found that the parting pots used in mints, formerly made of platinum at enormous cost, can be advantageously replaced by iron containing a certain percentage of either phosphorus or silicon, which will resist the action of acids even better than the more expensive metal. And if some means of casting ferro-silicon containing from ten to fifteen per cent. of silicon could be found it would be invaluable, since it has been shown that this substance is completely insoluble in aqua regia.

In connection with the note on page 311, Vol. VIII, the following abstract from the *Danbury (Ct.) News*, found in the *Boston Journal* of July 30, 1883, may prove interesting:

"A carboy of nitric acid broke in a car on the New York City and Northern road on its way to Danbury, Sunday evening. On its arrival here at 8 o'clock, a blue flame was seen to issue from its roof by Frank Wheeler, an employe of the New England Company.

Station Agent Pearce was notified, who made an examination and learned the cause of the trouble. He and several others immediately set to work to empty the car, a difficult and dangerous task, as the inside of the car was full of the destroying gas. One of the helpers was Harry N. Baker, in the employ of the New England Company. He went home after the car was cleared and was attacked with nausea. He was at work Monday morning, but shortly was taken ill and returned home, where he now lies in an unconscious state, and with no hope of his recovery. The physicians in charge say his lungs are coated with the poisonous gas."

On page 287, Vol. IX of the Proceedings, a resumé of Abbot's report on Submarine Mines is given. Gen. Abbot has now issued Addendum I to this report, embodying the results obtained with tonite, California gun-cotton and rackarock. The tonite had been manufactured in the United States for about a year by the Tonite Powder Company of San Francisco, under patents assigned by the Cotton Powder Company Limited of London, when in the summer of 1882 samples were procured for trial at Willet's Point. The shipment was made on the Pacific railroad. The works of the company, near Stege station on the Central Pacific, are reported to have a capacity of twenty tons monthly, and it is understood that similar works are to be erected in the East. The standard tonite made by the company consists of 52.5 parts of gun-cotton and 47.5 parts of nitrate of baryta; but for special purposes, and by request, a part of the latter is sometimes replaced by potassium or sodium nitrate.

Two varieties of the standard explosive were received—one dry in compacted cartridges, and the other damp in bulk. The damp as sent contained 18 per cent. of moisture, but when received it held but 13.5 per cent. The uncompressed damp tonite was detonated with dry tonite or gun-cotton. The relative efficiency in a horizontal plane as compared with dynamite No. 1 was found to be 0.81 for the dry compressed state and 0.85 for the other, giving as an average value 0.83. The explosive therefore takes rank just below gun-cotton (0.87). The result is not unlike what might be anticipated from the chemical composition of these two explosives, and it is evident that the substitution of a portion of nitrate of baryta tends rather to reduce than to increase the normal intensity of action of gun-cotton, pound for pound, when fired under water.

The Tonite Powder Company of San Francisco also manufactures

gun-cotton by a process which appears from their circulars to be essentially that of Prof. Abel—omitting the compression into cartridges. It was regarded as desirable to test this product at Willet's Point, in the usual manner, to learn how it compares in strength with that made in England. A sample was accordingly procured with the tonite in the summer of 1882. The explosive was delivered damp in the state of loose powder, which when dry became a fine white dust. The following statement respecting it was received from Mr. W. L. Oliver, general manager of company:

“Lot No. 3.—This is 120 pounds gun-cotton (pulverized) containing 24 per cent. of moisture. This lot of gun-cotton gave by assay 89.60 per cent. insoluble tri-nitro-cellulose and 10.40 per cent. soluble gun-cotton. This is not quite up to our average, which is about 93 per cent., owing to the acid of late being rather inferior; but nevertheless the gun-cotton is good, and is 7 per cent. above the standard required by the British Government. The test for purity and acidity from two samples stood 246° and 250° Fah. for 28 minutes, the British Government standard being 150° for 10; and these samples subjected to a long and steadily increasing temperature stood 358° and 360° before it flashed, and a fresh sample started at 200° stood 364° . Such gun-cotton will keep unaltered for many years in any climate.”

This gun-cotton was shipped across the country packed in a barrel. To determine whether, when actually tested, the explosive retained the full 24 per cent. of moisture, a sample of 400 grains was withdrawn from the bottom of the mass and desiccated to dryness. The loss proved to be 80.6 grains or only 20 per cent. These figures were used in estimating the charges in preference to those furnished by the company, because some loss of moisture was to be expected under the circumstances. The firing test showed this gun-cotton to be not inferior in explosive intensity to the best English manufacture, but in the form furnished it was so bulky that very solid packing was necessary to force 4.2 pounds into a No. 2 can, which will readily receive 10 pounds of dynamite in loose powder. This bulk would be a fatal objection for use in ground mines, but would be perhaps an advantage in buoyant torpedoes.

The Rackarock, supplied by the Rendrock Powder Company of New York, was brought to Gen. Abbot's notice in the winter of 1882, by one of the manufacturers. It consists of a solid, composed mainly of potassium chlorate, in fine powder, given a reddish tint by some

coloring matter ; and of an oily liquid, having the strong, bitter almond smell characteristic of nitro-benzol. These compounds, neither of which is explosive by itself, are combined before use by immersing the solid in the liquid for a few seconds until an increase in weight of about one-third is effected by absorption. The solid is supplied in the form of loosely packed cartridges of different sizes, put up in bags closed at each end. The combination of the ingredients is effected by means of an open basket of wire to receive the cartridges, which is suspended from a spring balance and dipped in a galvanized iron pail containing the fluid. A little attention to the time of immersion renders the absorption fairly uniform. The explosive, when prepared in this manner, is a compact red solid, having a specific gravity of about 1.7. It decrepitates with difficulty when hammered on an anvil, but hardly ignites on wood. A fuse containing 24 grains of fulminating mercury fails to explode a cartridge unconfined or loosely confined. Even if it be compacted in an auger-hole in a log and tamped with mud the explosion is only partial. A cartridge struck by a bullet from a Springfield rifle flashes but does not detonate. Ordinary friction seems to have little tendency to cause explosion. These facts show it to be quite safe to handle even when ready for use, and it has given excellent results in rock-blasting under General Newton at Flood Rock. Its peculiar chemical composition gives rackarock the interest of novelty among modern high explosives, and it has accordingly been tested with special care to discover the intensity of action of which it is capable when fired under water. Two fluids were supplied for the trials—the usual one consisting essentially of nitro-benzol ; and the other, of a special preparation consisting of the same saturated with picric acid (12 to 16 per cent. according to the quality of the solvent). The explosives prepared by absorbing these fluids by the solid are designated as “rackarock” and “rackarock special.”

The results of the firing tests showed that rackarock, fired under water, gives a relative efficiency in the horizontal plane of 0.86, being nearly equivalent to gun-cotton, and a study of the results proved that there is no difference in the intensity of action between rackarock and rackarock special, which exceeds the range of variation with either of them, but there was a considerable variation with each of them. That this should be so in a mixture of which the ingredients are combined by the rough method described above is not surprising. Moreover, nitro-benzol itself (formed by treating crude benzene with fuming nitric acid) is certainly subject to important variations in

chemical composition, due to its impurities ; and the same is probably true of the solid as supplied in the trade cartridges.

The anomalous variations noted were confined to the firing of two days. It is to be regretted that the causes which produced the excessive pressures could not be detected, for if the peculiar conditions corresponding to the greatest intensities of action could always be fulfilled this explosive would take rank with explosive gelatine itself instead of with gun-cotton for use under water.

Gen. Abbot concludes that "rackarock possesses the merits of high intensity of action, unusual density, absolute safety in handling and storage (components unmixed) and little cost ; on the other hand, under the conditions of my tests, an exceptionally strong detonating primer is essential to develop its full power. Experiment alone can determine whether this defect be equally marked when the charges are confined in drill holes in solid rock." It will be observed that rackarock belongs to the class of explosives invented by Dr. Sprengel and noted on page 670, Vol. VIII of these Proceedings.

For comparison of the relative efficiency of explosives I add the following table taken from Gen. Abbot's *Submarine Mines*, p. 110.

Relative Strength of Explosive Compounds Fired Under Water.

Explosive.	Percentage of nitro- glycerine.	Value of <i>E</i> .	Relative intensity of action.		
			Downward $\vartheta = 0^\circ$.	Horizontally $\vartheta = 90^\circ$.	Upward $\vartheta = 180^\circ$.
Dynamite No. 1,* .	75	186	100	100	100
Gun-cotton, .	...	135	81	87	91
Dualin, . .	(?)	232	116	111	108
Rendrock, . .	20	101	67	78	84
" . .	40	160	91	94	95
" . .	60	166	93	95	96
Dynamite No. 2, .	36	120	75	83	88
Vulcan powder No. 1, .	30	99	66	78	83
" " No. 2, .	35	114	72	82	86
Mica powder No. 1, .	52	119	74	83	87
" " No. 2, .	40	46	39	62	73
Nitroglycerine, .	100	111	71	81	86
Hercules No. 1, .	77	211	109	106	105
" No. 2, .	42	118	74	83	87
Electric No. 1, .	33	67	51	69	77
" No. 2, .	28	43	38	62	72
Designolle, .	0	65	50	68	77
Brugere, . .	0	110	71	81	86
Explosive gelatine, .	89	259	125	117	113

* Standard of comparison.

NAVAL INSTITUTE, ANNAPOLIS, MD.

FEBRUARY, 1884.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY PROF. CHARLES E. MUNROE, U. S. N. A.

No. VI.

In No. V of these Notes we have referred to Berthelot's lectures on Explosives. These have now been reprinted by Van Nostrand as No. 70 of his *Science Series*. We then proposed to present later his discussion of the theories suggested to account for explosions induced by the influence of contiguous explosions, and hence we extract the following.

In discussing the duration and speed of propagation of explosive reactions Berthelot has regarded the development of the explosive reactions either from the point of view of their duration in a homogeneous system in which all the parts are maintained at the same temperature, or else from the standpoint of their propagation in a system equally homogeneous, to which fire is applied directly by means of a body in ignition, or else by a violent shock. In these later years, however, the study of explosive substances has revealed the existence of another method of propagating the reactions from an explosive centre, this propagation taking place at a distance and by the intermediation of the air or certain solid bodies which do not themselves participate in the chemical change.

We shall now speak of what are called explosions by influence, whose existence was formerly suspected from certain known facts connected with the simultaneous explosion of several buildings separated by considerable space from each other, as in catastrophes

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars.

occurring in powder mills. Attention has been especially directed to this class of phenomena by the study of nitro-glycerine and gun-cotton.

We will begin by giving the most important characteristic facts. A dynamite cartridge made to detonate by means of a fulminate cap causes the adjoining cartridges to detonate, not only by contact and by direct shock, but even from a distance. In this way an indefinite number of cartridges, arranged in a regular course, may be made to detonate.

The distances to which the explosion may be propagated are relatively great. Thus, for instance, with cartridges contained in rigid metallic envelopes and placed on a resisting soil, the detonation produced by 100 grams of Vonges dynamite (75 per cent. of nitro-glycerine and 25 per cent. randanite, which is very finely divided silica) communicates itself 0.3 meter, according to the experiments of Captain Coville. D being equal to the distance in meters and C the weight of the charge in kilograms, the experiments of this officer show that $D = 3.0C$. When the caps were laid on a rail D was found to be equal to $7.0C$. On soft or ploughed-up earth the distances, on the contrary, are less. When a cartridge is suspended in air there is no detonation by influence, perhaps because the cartridge not being fixed can recoil freely, which diminishes the violence of the shock. Nevertheless there are experiments which show that the air suffices for the transmission of the detonation by influence, although with greater difficulty and requiring a greater mass of the explosive. With a dynamite less rich in nitro-glycerine (55 per cent. of nitro-glycerine and 45 per cent. of the argillaceous ashes of bog-head coal), contained in similar cartridges, and placed along the ground, the experiments of Captain Pamard have given the smallest distances: $D = 0.90C$. If metallic envelopes having less resistance are used, the distance at which the explosion is propagated is likewise diminished. Dynamite simply spread along the ground ceases to propagate the explosion. The experiments performed in Austria have given similar results. They have shown that the explosion is communicated either in the free air with intervals of 4 cm., or else through pine boards 18 mm. thick. In a lead tube with a diameter $= 0.15$ meter and a meter in length, a cartridge placed at one extremity has caused the detonation of a cartridge at the other end. The explosion is still better transmitted through tubes made with wrought iron. The couplings of the tube diminish its aptitude for transmission.

An explosion which is propagated in this manner will go on weakening itself from cartridge to cartridge and even change its character. Thus according to the experiments made by Captain Müntz at Versailles, in 1872, a first charge of dynamite exploded directly, excavated a funnel-shaped hole in the ground with a radius of 0.30 meter; the second charge, detonated by influence, produced an opening of only 0.22 meter; the effect of the detonation was then reduced. This reduction should manifest itself towards the limit of the distance at which the influence ceases. In the same way four tin screens were located 40 mm. apart, a small cylinder of gun-cotton was placed against each of them, and the entire affair arranged on a board; 15 mm. in front of the first screen a similar cylinder was detonated. All of the cylinders detonated, but a progressive diminution was observed in the indentations produced in the board below each cylinder. According to these facts the propagation by influence depends at the same time on the pressure acquired by the gas and on the nature of the support. It is not even necessary that it should be rigid.

Finally, in operating under water at a depth of 1.30 meters, a charge of 5 kilograms of dynamite brought on an explosion of a charge of 4 kilograms situated at a distance of 3 meters. The water then transmits the explosive shock, at least to a certain distance, as does a solid body. This transmission is so violent that the fish are killed in ponds within a sphere of a certain radius by the explosion of a dynamite cartridge.*

Similar experiments have been made by Abel with compressed gun-cotton. According to his observations the explosion of the first block determines that of a series of similar blocks. The propagation under water has likewise been studied; the explosion of a torpedo charged with fulminating cotton caused the detonation of adjoining torpedoes placed within a certain radius of activity. The sudden pressure transmitted by the water when measured by means of the compression of lead at different distances, such as 2.50 m., 3.50 m., 4.50 m., 5.50 m., goes on decreasing, as would be expected. Besides, experiment has shown that the relative position of the charge and of the "crusher" is of no consequence, which is in harmony with the principle of equal transmission in all directions of hydraulic pressures.

* For further data, see Abbot's *Submarine Mines*, pages 54 and 122.

Explosions of fulminating substances which are rapidly propagated to a great number of caps, belong to this same order of explosions by influence. We have previously cited the explosion in the Rue Beranger.* The experiments which M. Sarrau made on that occasion showed that caps of the description which produced this catastrophe may be successively burned in a fire without giving rise to a general explosion; whereas the explosion of a few of these same caps, each containing 10 milligrams of explosive material, if it is provoked by a rapid pressure, determines by influence the explosion of the adjoining packages, even when they are not contiguous and are situated at a distance of 15 centimeters apart. A general explosion may thus easily be produced by influence. It follows then from these facts, and especially from the experiments made under water, that the explosions by influence are not due to inflammation, properly so called, but to the transmission of a shock arising from the enormous and sudden pressures produced by the nitro-glycerine or the gun-cotton.

Let us enlarge upon this explanation; it is the same fundamentally as that which we have already shown as accounting for the influence of the shock which determines the direct detonation of explosive substances.

In an extremely rapid reaction, the pressures may approach to the limit which corresponds to the matter detonating in its own volume, and the commotion due to the sudden development of almost theoretical pressures can be propagated both through the ground and supports as intermediary, or through the air itself, projected *en masse*, as has been shown by the explosion of certain powder factories and of gun-cotton magazines, and even by some of the experiments with dynamite and compressed gun-cotton. The intensity of the shock propagated either by a column of air or by a liquid or solid mass varies with the nature of the explosive body and its mode of inflammation; it is of greater violence according as the length of the chemical reaction is shorter and develops more gas, that is to say, a higher initial pressure, and more heat, and consequently work, for the same weight of explosive material.

This transmission of a shock is conveyed better by solids than by liquids, better by liquids than by gases; with gases it becomes better as they are more compressed. Through solids it is better propagated according to their degree of hardness, iron transmitting

* Nav. Inst. Proc. 9, 752.

it better than earth, and hard ground better than ploughed soil. All breaks of continuity in the transmitting material tend to weaken it, especially if a softer substance is interposed. Thus it is that the use of a tube made from a goose-quill, as a receiver, stops the effect of mercury fulminate, while a tube or a capsule of copper transmits this effect in all its intensity. The explosion by influence is the better propagated in a series of cartridges according as the envelope of the first detonating cartridge is the more resisting, which allows the gases to attain a greater pressure before the covering is destroyed. The existence of an empty space, that is to say, filled only with air, between the fulminate and the dynamite, on the other hand diminishes the violence of the shock transmitted, and in consequence that of the explosion; generally the effects of breaking powders are lessened when there is no contact. To form a full conception of the transmission of sudden pressures which produce shock by the supporting medium, it is desirable to recall this general principle, in virtue of which, in a homogeneous mass, pressures are transmitted equally in all directions, and are the same on a small element of surface whatever its position. Detonations produced under water with gun-cotton show that this principle is equally applicable to the sudden pressures which produce the explosive phenomena. But it ceases to be true when one passes from one medium to another.

If the inert chemical matter which transmits the explosive movement is fixed in a given situation on the surface of the ground, or better, on the surface of the rail on which the first cartridge was placed, or better still, held by the pressure of a mass of deep water in the midst of which the first detonation is produced, the propagation of the movement in this matter will hardly be able to take place, except under the form of a wave of a purely physical order, and consequently of an essentially different character from the first wave of a chemical and physical order simultaneously developed in the explosive body itself. This new wave propagates the concussion away from the explosive centre all around it, and with an intensity which decreases inversely as the square of the distance. Even in the neighborhood of the centre, the displacements of the molecules may break the cohesion of the mass and disperse it, or crush it by enlarging the chamber of explosion, if the operation is conducted in a cavity. But at a very short distance (the magnitude of which depends on the elasticity of the surrounding medium) these movements, confused at the beginning, arrange themselves in such order as to produce a wave,

properly so called, characterized by compressions and sudden deformations of the material, the amplitude of these oscillations depending upon the magnitude of the initial impulse. They move with a very great rapidity, and preserve their regularity up to the point where the medium is broken; then these compressions and sudden deformations change their nature and are transformed into a movement of impulse, that is to say, they reproduce the shock. If then they act on a new cartridge they may determine its explosion; the shock will be otherwise weakened by the distance, and in consequence the character of the explosion may be modified. The effects diminish in this manner up to a certain point from which the explosion ceases to produce itself. When this occurs on a second cartridge the same series of effects will be produced from the second to the third cartridge; but they depend on the character of the explosion of the second cartridge. And thus it goes on.

Such is the theory that appears to me to explain explosions by influence and the phenomena which accompany them. It depends, definitely, on the production of two orders of waves: one series represents the explosive waves, properly so called, developed in the midst of the matter which detonates, and consists of a continually reproduced transformation of the chemical actions into thermal and mechanical actions, which transmit the shock to the support and to the contiguous bodies; the other is a purely mechanical and physical series, which transmits equally the sudden pressure all around the centre of the concussion to the adjoining bodies, and by a singular circumstance to a new mass of explosive material.

A theory differing from this was originally proposed by Abel. It is the theory of *Synchronous vibrations*. According to this English savant the originating cause of the detonation of an explosive lies in this synchronism between the vibrations produced by the body which provokes the detonation and those which the first body would produce in detonating, precisely as a violin string resounds at a distance in unison with another vibrating chord. Prof. Abel has recited the following facts in support of his theory. To begin with, the detonators appear to differ with each variety of explosive. For instance, nitrogen iodide cannot cause the detonation of compressed gun-cotton. Nitrogen chloride will not produce the same detonation except when ten times as much weight is used as of the fulminate necessary. Likewise nitro-glycerine will not produce a detonation in sheets of gun-cotton on which is placed a case containing nitro-glycerine. In

this way nitro-glycerine up to 23.3 grams can be detonated without effect. On the other hand, 7.75 grams of compressed gun-cotton have caused the detonation, at a distance of 25 mm., of nitro-glycerine wrapped up in an envelope of thin sheet-iron. Likewise, according to Brown, a cap filled with a mixture of potassium ferrocyanide and potassium chlorate will not detonate gun-cotton. Finally, according to Trauzl, a cap consisting of a mixture of mercury fulminate and potassium chlorate should be of much heavier weight than if it be filled with the pure fulminate; nevertheless, the heat given off by the same weight is greater by one-fifth with the first mixture.

Messrs. Champion and Pellet have brought to the support of this ingenious hypothesis the following experiments: They attached to the strings of a double bass particles of nitrogen iodide, a substance which detonates on the slightest friction. Then they made the strings of a similar instrument vibrate at a short distance off; a detonation was produced, but only for sounds higher than a certain note which corresponds to 60 vibrations per second. They also took two conjugate parabolic mirrors, placed 2.5 meters apart, and they arranged along the line of the foci at different points several drops of nitro-glycerine or of nitrogen iodide; they then detonated at one of the foci a large drop of nitro-glycerine; they observed that the explosive substances placed in the conjugated foci detonated in unison, to the exclusion of the same substances placed at the other points. A layer of lamp-black placed on the surface of the mirrors was designed to prevent the reflection and the concentration of the heat-rays.

As yet none of the experiments appear to me to be conclusive, and several of them seem even to be directly opposed to the theory. We shall begin by observing that the characteristic feature of a given musical note, capable of determining each variety of explosion, has never been established. It is only below a certain note that the effects cease to be produced, while they take place by preference, whatever the explosive bodies may be, by the action of the most acute notes. Besides, these effects cease to produce themselves at distances which are incomparably less than the resonance of the chords in unison, which goes to prove that the detonations are functions of the intensity of the mechanical action, rather than of the character of the determining vibration. Similarly, the detonation ceases to be produced when the weight of the detonator is too slight, and in consequence when the mechanical energy of the shock is weakened. Nevertheless, the specific vibratory note which determines the ex-

plosions should always remain the same. For instance, cartridges filled with 75 per cent. of dynamite cease to detonate when the capsule contains a weight of fulminate less than 0.2 gram, the detonation only being assured in all cases by the regulation weight of one gram. This confirms the existence of a direct relation between the character of the detonation and the intensity of the shock produced by one and the same detonator.

If it is true that gun-cotton will cause the nitro-glycerine to detonate in consequence of the synchronism of the vibration communicated, then we do not understand why the reciprocal action does not take place; while the absence of reciprocity can be easily explained by the difference of the structure of the two substances which plays so important a part in the transformation of the mechanical energy into work.

This same diversity of structure and the modifications which it introduces into the transmission of the phenomena of the shock and the transformation of the mechanical energy into thermal energy, may be cited to explain the facts observed by Abel.

The difference between the energy of pure fulminate and of the fulminate mixed with potassium chlorate is no less easily explained; the shock produced by the first body being sharper on account of the absence of all dissociation of the product (which is no other than carbon monoxide), this absence should be contrasted with the dissociation of carbon dioxide formed in the second case. Perhaps, also, the formation of potassium chloride disseminated through the gas produced, with the concurrence of potassium chlorate, weakens the shock, just the same as silicon does in the case of dynamite.

All the effects observed with nitrogen iodide may be explained by the vibration of the supports and by the effects of rubbing which result therefrom, this substance being particularly sensitive to friction. The experiment with the conjugate mirrors may also be easily explained by the concentration in the focus of the movements of the air, and therefore of the mechanical effects which result.

Besides, M. Lambert has proved by experiments made for the Commission on Explosive Substances, that in the explosion of dynamite cartridges in tubes of cast iron of large diameter, regarded from the standpoint of detonations by influence, there does not appear to be any difference between the ventral segments and the nodes characteristic of the tube.

Desiring to clear up this entire question by removing it from the influence of the support and of the diversity of cohesion and physical

structure of solid explosive substances, I undertook a series of special experiments on the chemical stability of matter in sonorous vibration, and especially on that of gaseous bodies such as ozone, hydrogen arsenide, or liquids such as hydrogen peroxide and persulphuric acid, all of these bodies being selected from among those which decompose or change spontaneously at ordinary temperatures with the disengagement of heat, precisely as explosive substances do. The description of these experiments may be found in the *Comptes Rendus* or in the *Revue Scientifique*, May, 1880.

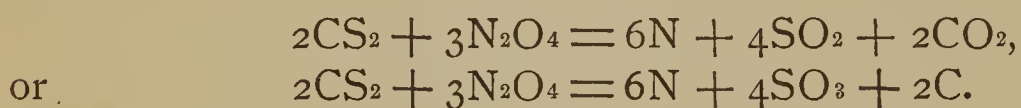
They lead to the conclusion that substances, which are transformable with the disengagement of heat, are stable under the influence of sound waves, while they are decomposed under the influence of ethereal vibrations. This diversity in the mode of action of the two classes of vibrations is not surprising when we consider that the most acute sonorous vibrations are incomparably slower than the luminous or thermal vibrations.

Hence it appears certain that the propagation of explosions by influence is not made in virtue of an undulatory movement, which is a complex motion of a chemical and physical order in the midst of the explosive substance which is decomposed, while it is purely physical in the midst of intermediary substances which suffer no decomposition; but that which distinguishes this sort of movement of the vibrations, properly so called, is, first of all, its extreme intensity, that is to say, the magnitude of the mechanical energy which it transmits; it is also the unique character of the explosive wave, which is propagated in contradistinction with the multiplicity of successive sonorous waves. Finally, it is essential to observe that the explosive material does not detonate because it transmits the movement, but on the contrary because it arrests it, and because it transforms on the spot the mechanical energy into thermal energy, capable of suddenly raising the temperature of the substance up to the degree which will produce its decomposition.

On page 670, Vol. VIII, we have referred to a new explosive called Panclastite, invented by Eugene Turpin. We are now in possession of a brochure* by the inventor, and from this we learn that the substance is made by mixing liquid nitrogen tetroxide (N_2O_4) with com-

* Notice sur la Panclastite découverte par Eugène Turpin. Paris, E. Bernard et Cie, 1882.

bustible substances such as the hydrocarbons; vegetable, animal and mineral oils; fats and their derivatives, but preferably with carbon disulphide. He proposes that the two substances should be kept apart until needed for use, when they may be mixed in the proportions considered best for the work in hand. The proportions which yield the most sensitive mixture are $2\text{CS}_2 + 3\text{N}_2\text{O}_4$, being about two volumes of the first to three volumes of the second. In making this mixture the temperature falls about 20° . When equilibrium is re-established the mixture burns with a most brilliant flame if ignited when freely exposed to the air. If confined in a vessel and ignited it burns until the pressure of the gases produces an explosion. Under these circumstances only a portion of the enclosed matter explodes and the remainder burns up quietly. If however it be exploded by a fulminate primer, whether confined or freely exposed, the explosion is complete and powerful; more powerful, it is claimed, than nitroglycerine or explosive gelatine. The reactions attending these different modes of decomposition vary. When the pancrastite burns freely it leaves a deposit of sulphur, and sometimes of colorless crystals which yield nitrogen dioxide when brought in contact with water. When the pancrastite is detonated carbon is deposited as a black residue. The author suggests that the reactions made be represented thus:



The deposition of sulphur can only be explained by supposing a deficiency of nitrogen tetroxide. The formation of nitrogen dioxide or monoxide cannot be admitted, since carbon disulphide burns equally well with these two gases.

The advantages claimed for this explosive are greater power than dynamite, perfect safety of the separate constituents in transport and storage, insensitiveness of the mixture to blows, and easy control of the manufacture by the government, owing to the fact that nitrogen tetroxide is not met with in commerce.

The power is shown in the results of several experiments cited, where rocks and rails were broken and cylinders of lead compressed. Thus where 400 grams of dynamite No. 1 broke blocks of stone into 5 or 6 portions, 150 grams of pancrastite broke them into 28 to 32 portions. In testing the sensitiveness a hammer weighing six kilograms—

Exploded	gunpowder	in falling	0.50	meters.
"	gun-cotton	"	0.25	"
"	dynamite No. 1	"	0.15	"
"	gum dynamite	"	0.20 to .25	"
"	nitro-glycerine	"	0.10 to .15	"
had not	panclastite (liquid)	"	4.00	"

The sensitiveness can however be varied at will, and the material used in this experiment was the least sensitive of the mixtures.

In general panclastite is to be used in the liquid state, but if the solid state is preferred it may be absorbed by infusorial silica just as nitro-glycerine is.

M. Turpin proposes to utilize the light-giving power of panclastite, and has devised a lantern for burning the liquids which is very similar in construction to the oxyhydrogen lantern without the lime cylinder. He believes this may be used as a signal or search light in the field or for photographic purposes.

The heat developed by the combustion is also very great, being estimated at about 3000° C. Platinum fuses instantly under the action of this flame, and the mixture can fuse its own weight. Graphite also commences to fuse. Turpin has also devised a furnace by which this source of great heat may be utilized in the arts. All of these devices are represented in large phototypes.

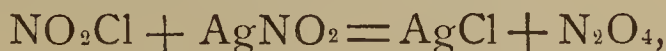
Nitrogen tetroxide may be produced by heating lead nitrate,



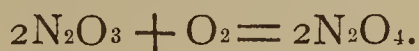
by acting on tin with nitric acid,



by acting on nitryl chloride with silver nitrate,



by union of oxygen with nitrogen trioxide,



When the nitrogen tetroxide gas formed by the above processes is passed into a freezing mixture of salt and ice it condenses in transparent crystals which melt at -9° , and which when once melted do not resolidify until cooled to -30° . Above -9° it forms a mobile liquid (sp. gr. 1.451) which boils at 22° . If water is present in the condenser the substance does not crystallize. Nitrogen tetroxide

probably undergoes dissociation at a comparatively low temperature. At 100° the gas consists chiefly of NO_2 , at ordinary temperatures of N_2O_4 , and at intermediate temperatures the gas is a varying mixture of these two. The liquid, at ordinary temperatures, gives off an abundance of reddish vapors, which, when mixed with air, are extremely difficult to condense. These vapors have a pungent, suffocating odor, an acid taste, are quite irrespirable, and stain the skin of a bright yellow. When mixed with water at a low temperature it is decomposed into nitric and nitrous acids; at an ordinary temperature, into nitric acid, water, and nitrogen dioxide. The results of the determination of its specific heat are given on page 443, Vol. VIII of these Proceedings. The heat of combination of the gas is -24.3 , of the liquid -20 .

The *Notes on Explosives* of W. N. Hill have been regarded as a most valuable and trustworthy guide to this study. The recent limited edition having been exhausted, we extract the following new notes, which correct, explain or extend the statements and descriptions of former editions.

The features of the nitro-glycerine process which are of the greatest importance are the strength of the acids and the complete washing of the products. The nitric acid should be of the greatest strength, since upon this depends the completeness of the conversion. With such acid, the maximum production of nitro-glycerine is attained and the oxidizing action is lessened. Also in such case the heat of the operation is much reduced, and the temperature of the reaction becomes of less importance. With the strongest acid the limits of temperature heretofore assigned may be considerably exceeded without injurious result. It has been stated that the mixing of the glycerine with the acid should be slowly performed. This should be understood to mean that the mixing is to be slowly performed, in order to preserve a low temperature during the operation; but, if the temperature is within the limit, the mixing should be performed as rapidly as possible, and the nitro-glycerine removed from the sphere of action. Rapidity of working is largely dependent upon the quality of acids employed, since the heat evolved is least when the strongest acid is used. In general with highly concentrated acid, not only is the proportional product increased, but also the reaction goes on more uniformly and is more easily controlled.

The manufacture of nitric acid for this purpose cannot be considered here, but it should be stated that acid for making nitro-glycerine is

now largely sold in the form of "mixed acid"—that is, the mixture of nitric acid and sulphuric acid ready for use. Much of this, however, does not come up to the standard which should be set up. The degree of strength of the nitric acid given before is too low. Acid of 1.49 to 1.51 specific gravity (48° – 49° B.) should be taken, and this strength should be real and not factitious, as is often the case with acids nominally testing 50° and 52° Baume. To prepare such acid requires special care and precaution. The method of redistillation from oil of vitriol in glass retorts furnishes the finest acid, and in the writer's hand has worked extremely well, but it involves some trouble and expense.

The proportion of nitro-glycerine obtained is dependent almost entirely upon the acid used. If the glycerine is weak the product will fall off, but the small difference in strength of glycerine ordinarily found exercises little effect. But if the acids are weak the product is markedly less. This does not depend to any extent upon the method or form of apparatus operated, but only upon the acid taken. Weak acids will carry smaller quantities of glycerine and give lower proportional products than strong ones. Consequently, statements of relative products obtained are of comparatively little value unless accompanied by a statement of the kind of acid employed and the relative amount of glycerine treated. We have stated that in operating practically 1.6 to 1.75 parts of nitro-glycerine to one of glycerine were obtained, but that with the strongest nitric acid 1.96 to 2.03 parts were produced on a small scale. These figures are too low. It is not difficult to practically carry the proportion to rather more than two to one, using one part of glycerine to 7.5 or 8 parts of acid (mixed). With some care in the preparation of materials 2.2 parts can be obtained.

The method of making nitro-glycerine fully described in the body of this work is a convenient one from simplicity of apparatus, and has been found serviceable for the occasional requirements of the torpedo station. But for steady work on a large scale it is not as desirable as other methods of operating. The handling of small quantities of material takes much time and labor, and the reaction goes on more steadily and regularly with larger masses of material. The simplest, and a very effective method, is to use a large amount of the mixed acid (2000 to 3000 lbs.) in a large leaden or iron tub, containing also coils of pipe through which cold water is forced; this tub is set within another of wood, and the annular space between is traversed by

cold water ; agitation of the acid is brought about by agitators driven by power (in some cases the agitators are driven by hand, but this is very objectionable). The glycerine is run in through an opening in the cover of the tub and distributed so as to fall upon the acid in a number of fine streams. The temperature is observed by a thermometer passing through the cover. When the desired amount of glycerine has been run in, the contents of the tub are drawn off into water and the nitro-glycerine separated.

In another form of apparatus a leaden tank is placed within a wooden one, so that water can be passed between them ; in the tank revolves a hollow shaft, carrying paddles for a portion of its length, and for the remainder a cylinder, so that cold water may be led through the shaft and cylinder. The glycerine falls upon the surface of the revolving cylinder and is so conveyed into the acid, which is agitated by the paddles.

Different in principle is the process of Boutmy* and Faucher. In this the glycerine is mixed with half the sulphuric acid and the mixture allowed to cool. This is then added to the mixed acid (the nitric acid with the remainder of the sulphuric), the whole allowed to stand for twenty-four hours, and then thrown into water to separate the nitro-glycerine. Special advantages are claimed for the method, but it is doubtful if these claims are well founded. It is stated that it is more free from danger than others, and that it gives a large yield. With proper care the operation of conversion is not a dangerous one, and accidents at that stage are extremely rare by any method. The yield claimed is not in advance of that usually obtained, and, as already pointed out, the yield is governed by the quality of the acid used. This method is open to the grave objection that a large proportion of the nitro-glycerine is in contact with strong acid for a considerable time.

In Kurtz's method the vessel containing the acid is a narrow cylinder, with conical bottom of lead or iron, placed vertically. Two pipes extend to the bottom of this cylinder, one delivering glycerine and the other compressed air. The openings of these pipes are opposite to one another, so that the air-current strikes the glycerine and quickly diffuses it through the acid. The nitro-glycerine formed is supposed to rise to the surface of the liquid, and run off through a pipe to the washer. In another form of Kurtz's apparatus air is forced

* Nav. Inst. Proc. 5, 15.

into the glycerine, making a kind of emulsion, which is driven into the acid in the converting vessel by air pressure.

In all forms of apparatus for making nitro-glycerine the greatest care must be taken to prevent any accidental admixture of water with the charge in the converter. A very little water shows itself by the greater trouble and slowness experienced in running, and the product falls off. But if more water enters, the heat developed would be greater than can be carried away by the usual means of cooling and the charge is "fired." Usually this means only an active decomposition, accompanied by clouds of nitrous vapors. Slight "fires" may be stopped by vigorous agitation, but if the firing is persistent the contents of the tub should be run off as rapidly as possible. During drawing off, constant agitation of the liquid should be made to prevent separation of nitro-glycerine. Washing with water is the only mode spoken of. It is not difficult to wash nitro-glycerine thoroughly with water only, but the treatment must be continued until the washing is complete. This requires considerable time and labor. It is usual in manufacturing, therefore, to use an alkaline solution (sodium carbonate) to assist and expedite the washing process.

Hill has heretofore stated that frozen nitro-glycerine could not be fired. This is an error, it can be fired, but with much greater difficulty than when in the liquid state. In many later experiments he has often both failed and succeeded in exploding the frozen material, with the usual and larger amounts of fulminate.

Nitro-glycerine is but little used in the liquid state. In this country the principal use made of it in this condition is for "torpedoing" oil-wells. But for most purposes, such as mining, quarrying, engineering work, etc., the liquid is very rarely taken, while powders of which it is an essential ingredient are very largely employed. There are very few instances in which the intense and local action of liquid nitro-glycerine is demanded, but the field for the application of nitro-glycerine powders, which are more powerful and violent than ordinary blasting powder, is very extensive. These powders are of many kinds and many names. They may be considered in two ways:

1st. As nitro-glycerine preparations whose power and usefulness depend essentially upon the proportion of that substance which they contain; and 2d, according to the absorbent with which the nitro-glycerine is mixed. The nitro-glycerine is the valuable ingredient of all these powders. The principal object of their manufacture is to present nitro-glycerine in a safer, more manageable and more

useful form. They are made containing from 5 to 75 per cent. of nitro-glycerine. The lowest grades—5 to 10 per cent.—stand nearly on a level with ordinary blasting powder in regard to force and the purposes for which they are used. The powders ranging from 20 to 75 per cent. include most of the so-called high explosives now so largely manufactured in this and other countries. Those containing from 30 to 60 per cent. are the most extensively used. Serviceable powders must retain their nitro-glycerine at all practical temperatures, but must not be too dry, as they are then more difficult to handle.

In some powders the vehicle or solid matter with which the nitro-glycerine is mixed is entirely inert (for example, the silicious earth from which Nobel's dynamite is made), while in others the absorbents are substances themselves capable of decomposition or action either directly or under the powerful influence exercised by the nitro-glycerine explosion, so that they affect the resultant force exerted. From this we have the classification adopted by some writers, of preparations having an inactive base and those having an active base; but this classification is not satisfactory, since it is the nitro-glycerine which is the essential and important constituent, and since the bases or vehicles used are not definite substances or mixtures; therefore, although the absorbent materials might be such as could form an active base, yet from the proportions or manner of admixture employed they may practically exert no influence. The character of the absorbent may exercise influence upon the explosion of the powder in several ways. It may be composed of bodies which will react and add to the gas generated and so to the force exerted. Its physical condition may be such as to contain the nitro-glycerine in a state favorable to its best use. Also upon it depends the density of the finished powder, a matter of considerable practical importance.

Of the powders with inert absorbent, Nobel's or Kieselguhr dynamite is a good example. Another is the Magnesia Powder, or Hercules No. 1, in which carbonate of magnesia is the absorbent. Still another is the Cellulose Dynamite of Trauzl, in which purified wood pulp is the vehicle. These are rich powders—70 to 80 per cent. of nitro-glycerine—and are but little used commercially. They are well adapted for military purposes and are so applied.

There are very many kinds or varieties of the lower grades of nitro-glycerine powders, but essentially they are much alike in general composition. As the quantity of nitro-glycerine to be taken up is

moderate, great absorptive capacity is not required. Usually the absorbent is a mixture composed of nitrate of soda with one or more combustible substances, such as sawdust, wood pulp, charcoal, coal, rosin, etc., etc. If in such a preparation the nitrate and the combustible are properly proportioned and thoroughly mixed, they take part in the reaction and add force to the result. But in many cases these materials are in such bad proportions, or so imperfectly mixed, that little or no valuable action can take place between them. In this connection it is not necessary to enter into detailed descriptions of particular powders to be found in the market. Those of this class are less valuable for military use than the richer ones, but of course can be made to serve quite well for torpedoes, etc., in case of need.

Explosive gelatine or gelatine dynamite is made by dissolving photographic gun-cotton in nitro-glycerine, or by mixing nitro-glycerine with collodion, removing the solvent by evaporation. Nitro-glycerine, with the aid of heat, dissolves soluble gun-cotton, forming a gelatinous mass of firmness varying with the amount of gun-cotton contained. At 160°–170° F. solution of the gun-cotton and gelatinization quickly take place. In explosive gelatine the nitro-glycerine is very strongly retained, not being given up under heat or pressure. Explosive gelatine is very insensitive to blows and is not easily exploded, requiring a very powerful fuse, and is not injured by water. Various substances may be mixed with the materials used in preparing this agent to form mixtures of different kinds. Camphor dissolves freely in nitro-glycerine, so that camphorated explosive gelatine can easily be made containing it in any desired proportion. This preparation is even more insensitive to blows or other mechanical action than the simple gelatine. When struck by a rifle bullet fired at a distance of 80 feet it does not explode. To determine its explosion, either strong confinement or a peculiarly powerful fuse is required. In many respects explosive gelatine (particularly the camphorated variety) has special advantages for military purposes. It is considerably stronger than dynamite (75 per cent.) or compressed gun-cotton, and it is very free from liability to accident or injury in use or transportation. On the other hand its stability is a matter of question. Instances of its decomposition on keeping or after long exposure to moderate temperatures have been observed. It is probable that this difficulty may be removed. Soluble gun-cotton is apt to contain traces of free acid and to vary greatly in composition. Special care must be taken in making the gun-cotton to insure uniformity and

complete purification. If this tendency is overcome it is probable that explosive gelatine may be valuable for military purposes.

Some of the instances of decomposition of explosive gelatine have been cited in these Proceedings, Vol. VII, p. 486. In a prefatory note to Addendum I. of Gen. Abbot's report upon Submarine Mines, he states that "all the samples of the explosive gelatine remaining on hand after the trials detailed in the report have undergone spontaneous decomposition, separating into cellulose and free nitro-glycerine, with the copious evolution of nitrous fumes. This change occurred during the winter and spring of the current year (1881-1882), and was not caused by any exposure to high temperatures while in store."

A case of spontaneous decomposition of a small amount stored, freely exposed to air, in a dry room of even temperature, has occurred under my own observation. The camphorated explosive gelatine was wrapped in paraffine paper and then in light-brown wrapping paper. After something more than one year's exposure it was found in the early winter to be giving off nitrous fumes which had stained the wrapping paper, and to have shrunk considerably in volume, and that the outside of the paper was covered with congeries of fine crystals, while the odor of camphor was very strong. It was immediately put in a vessel of water, and after a short time the mass, which was friable, disintegrated. The camphor odor soon disappeared and the water became of a straw color, gave a strong acid reaction, and showed a slight trace of nitrous acid, but no nitric acid. On evaporation of the filtered liquid, oxalic acid crystallized out in quantity, and on evaporation of the mother liquid farther, on the water bath, a sugar-like mass was obtained which gave the glucose reaction with Fehling's solution.

The paraffine was regained unchanged and the paper was recovered, but in a flocculent condition, and with the color bleached from the brown. Careful search failed to reveal the presence of glycerine, nitro-glycerine or gun-cotton. The cellulose from the gun-cotton could not well be detected (if it existed) in the presence of so much flocculent cellulose from the paper.

The results obtained by De Luca in his "Researches on the Spontaneous Decomposition of Gun-Cotton," *Comptes Rendus*, 59, 487, September 12, 1847, are interesting in this connection. Gun-

cotton decomposes most rapidly when heated to 50° on a water bath, next by sunlight, more slowly by diffused light, and very slowly in darkness. The gun-cotton first shrinks to $\frac{1}{10}$ of its original volume, next it begins to become gum-like and sticky, then it swells; during all these phases it gives off nitrous fumes, but especially during the last. For the fourth phase the gas ceases to be evolved, and the mass becomes brittle and of a light color like sugar. The products are nitrous compounds with formic and acetic acids in the state of a gas, and an amorphous, porous, sugar-like body, almost entirely soluble in water and containing an abundance of glucose, gummy matter, oxalic acid, a small quantity of formic acid, and a new acid, of which he obtained the lead and silver salts for later examination. From 100 grams of gun-cotton he obtained about 14 grams of glucose.

As regards the decomposition of nitro-glycerine, A. Brull states, on page 26 of his "*Études sur la Nitro-glycérine*" (Paris, 1875), that concentrated sulphuric acid, concentrated nitric acid and concentrated soda solution attack nitro-glycerine even in the cold and provoke a progressive decomposition. Nitro-glycerine, which retains a trace of free acid, is not stable. In general, the decomposition is extremely slow and tranquil. It disengages at first nitrous vapors, the liquid taking a greenish color. Then there is formed nitrogen and carbon dioxides and crystals of oxalic acid, and after some months the entire mass is transformed into a greenish, gelatinous matter composed of oxalic acid, water and ammonia. Sometimes, if the temperature is high, as when heated by the sun, the decomposition is more active, but it very rarely causes an explosion.

Major W. McClintock, R. A., has been making a series of experiments with small shot in order to test the accuracy of various statements as to the strength of Schultze powder (sawdust powder) and E. C. powder (granulated gun-cotton), and also to determine the velocity when black gunpowder was used, since little was known concerning this. The Boulengé chronograph was used for measuring the observed velocities and Bashforth's tables were employed for calculating the remainder. All the cartridges used were bought from the same tradesmen, who obtained them direct from the factory, and although the method of loading was identical in all, and the powder (in those charged with gunpowder) was supposed not to vary in quality, it was found that no two boxes gave similar results. The cartridges were then examined, and it was almost invariably found that

the amount of powder was deficient and the weight of shot in excess. This deficiency of powder amounted in one case to 8 grains, and the excess of shot in the same cartridge to 64 grains. The powder too was found to vary in appearance and size of grain, and when some cartridges from each box were stripped and carefully reloaded with correctly weighed charges, the muzzle velocities showed that the powder varied very much in strength. These experiments show that the mean velocity obtained with *unweighed* charges should not be considered as proof of the quality of the cartridges, because one or two rounds which have a heavy powder, or light shot charge, may unduly raise the average. Taking weighed charges of 492 grains ($= 1\frac{1}{8}$ oz.) of shot, 82 grains ($= 3$ drams) of gunpowder, and from 45 to 47 grains of Schultze or E. C. powder, it was found that the average velocity of the last two was over 100 f. s. greater than gunpowder. The determined velocities of even the carefully made-up charges showed considerable variations, but source of error exists in the use of small shot, owing to the fact that the quickest pellets of the charge need not always cut the wires but may pass through the meshes. Major McClintock thinks that his experiments with the Schultze and E. C. powders were so few that it would be premature to form any decided opinions concerning them at present, but he states that these explosives possess great strength (sometimes too great), make little smoke and cause slight fouling, but the velocities they give are not regular. These experiments are given very much in detail, with copious tables, and are accompanied by an account of researches made to determine how the boring of the gun-barrels affects the muzzle velocity.—(*Proc. Roy. Artil. Inst.* **12**, 332, Aug. 1883.)

In these notes, Vol. VIII, p. 444, an abstract of the testimony in the case of the Atlantic Giant Powder Co. against the Dittmar Co. is given. Recently some of the papers in the suits of the same company against George A. Goodyear, George W. Townsend, Michael Brady, and the Neptune Powder Co. have come into our hands. The compositions of the various explosives which the Atlantic Giant Powder Co. regarded as infringements of their patents were as follows:

<i>Vulcan Powder.</i>					
Nitro-glycerine	.	.	.	.	32.60 per cent.
Nitrate of soda	.	.	.	.	49.46
Charcoal	.	.	.	.	9.63
Sulphur	.	.	.	.	8.31

Neptune Powder.

Nitro-glycerine	.	.	.	.	.	32.66 per cent.
Nitrate of soda	.	.	.	.	.	45.04
Charcoal	.	.	.	.	.	17.44
Sulphur	.	.	.	.	.	4.86
Ash	.	.	.	.	.	0.94

Miners' Powder Company Dynamite.

Nitro-glycerine	.	.	.	.	.	32.91 per cent.
Nitrate of soda	.	.	.	.	.	49.88
Charcoal, wood and partially charred wood	.	.	.	.	.	17.21
Ash	.	.	.	.	.	1.18

Brady's Dynamite or Vulcan Powder.

Nitro-glycerine	.	.	.	.	.	33.00 per cent.
Nitrate of soda	.	.	.	.	.	50.00
Charcoal	.	.	.	.	.	10.00
Sulphur	.	.	.	.	.	7.00

It will be observed that all these powders are practically dynamites in which gunpowder is used in place of infusorial earth as the absorbent. In regard to the powder made by Michael Brady, Thomas Varney, a manufacturer of nitro-glycerine, dynamite, &c., testifies that it "belongs to a class which is now quite large and known as high explosive powder. Some of their names are Giant Powder, Mica Powder, Vulcan Powder, Jupiter Powder, Neptune Powder, Thunderbolt Powder, Hercules Powder, Titan Powder, Rend-Rock Powder, Vigorite Powder, Lithofracteur Dualin.

"They are made by mixing nitro-glycerine with a dry pulverized substance, or mixture of substances such as have the capacity of taking up and holding a sufficient proportion of nitro-glycerine by absorption to make the mixture an effective explosive, and yet without being in such excess as to separate from the mass by leakage or compression, and at the same time the absorbent solids employed being such as will not chemically injure the proper explosive quality of the nitro-glycerine, and such as will render the mass practically inexplodable by concussions which ordinarily occur in handling and transportation. The solid ingredients, to-wit, the nitrate of soda, charcoal and sulphur, are first ground or otherwise pulverized, and dried if necessary. The nitro-glycerine is then carefully mixed with

them, so as to make a mass as nearly homogeneous as practicable, and the powder is then packed for market.

“ In the manufacture of Vulcan powder there is a combination of nitro-glycerine with absorbent substances which are the equivalents of infusorial earth ; and this combination constitutes an explosive compound, which has all the properties and qualities of the compound made by combining nitro-glycerine with infusorial earth in making dynamite or Giant powder, or with mica scales in making Mica powder, or with mealed gunpowder in making Vulcan powder.

“ In the first place, each of the materials used as absorbents in the Vulcan powder is solid. In the next place they are all free from any quality which will decompose, destroy or injure the nitro-glycerine. They are capable of pulverization. They are also dry, or may be made so. When pulverized each of them alone, or all of them in the proportions actually used, or in any other proportions, they will absorb and hold nitro-glycerine to the extent required by the patent sued upon, to-wit, enough to make an explosive powder without rendering the powder leaky, and without any explosive aid from the absorbents themselves.

“ Dry pulverized nitrate of soda will thus hold 30 per cent. of nitro-glycerine, charcoal 45 per cent., sulphur 30 per cent. (all these are explosive compounds), and when combined, as in Vulcan powder, they will thus hold 33 per cent.”

After asserting that the absorbent of the Vulcan powder is similar to the infusorial earth in converting the liquid nitro-glycerine into the solid form, he adds : “ The Vulcan powder absorbent, like that of the Neptune and Vigorite absorbents, has one quality not possessed by infusorial earth, to-wit, combustibility ; but this quality does not affect the powder as dynamite. Its only effect is to allow the absorbent to be burned by the heat of the exploding nitro-glycerine, thus adding gas and force to the explosion. Vulcan powder is no more combustible than dynamite of infusorial earth ; in fact, not as much so—that is, if an equal quantity of the two be set on fire, the Vulcan powder will burn the longest. Vulcan powder is practically as safe against concussion as infusorial earth dynamite.

“ This particular class of powders, with combustible absorbents, has been made and sold by the complainant since the commencement of its business, which was in October, 1871. It had previously been made and sold by Alfred Nobel & Co. and by the Giant Powder Company, and by no other person or party prior to its use by them,

to the best of my knowledge and belief. It has always been made and sold by the two Giant Powder companies, under the name Giant Powder No. 2, and labelled as patented under the original dynamite patent of May 26, 1868, and its reissues. Nobel & Co. have always made and sold it as Dynamite No. 2. The two Giant Powder companies have made and sold more of No. 2 than of No. 1—meaning by No. 1 infusorial earth dynamite, or Giant powder. The nitrates of our No. 2 have always been those of potash or soda. It has been the same with Vulcan powder. Our carbons have been rosin, bituminous coal, pulverized wood or sawdust. These have been our favorite materials, but we have experimented with and tried in practice for a longer or shorter time many other things. As to charcoal, one of the earliest things tried, we found it not so good as several other things. As to sulphur, we long ago abandoned its use. In gunpowder to be burned by itself it is useful as facilitating ignition; but when combined with nitro-glycerine it is not needed for this purpose, as the absorbent is readily fired by the exploding nitro-glycerine. For absorbing it is no better than the nitrate, and not as good as charcoal, or any of the carbons or hydrocarbons used in absorbents. In other words, the sulphur in Vulcan powder is useless for any purpose except as an absorbent, and for that purpose would be better replaced by the same amount of nitrate and carbonaceous matter.

“The fine pulverization of the Vulcan absorbent is mainly for the purpose of increasing its absorbent capacity. Ordinary well-grained gunpowder will not safely take and hold over ten per cent. of nitro-glycerine; but in the form of meal powder, its state before being grained, it will take and safely hold 45 to 50 per cent. The pulverization may be considered as having another advantage for purposes of absorbents, to-wit, the nitro-glycerine will be more intimately distributed in fine than in coarse materials, and the heat of the exploding oil will take effect quicker, and thus add force to the explosion.

“When Vulcan powder is exploded in practical use an exploder is always used. This exploder, by the force of its explosion, explodes the nitro-glycerine contained in the powder precisely as the nitro-glycerine is exploded in No. 1 Dynamite. The explosion of the nitro-glycerine in No. 1 does not affect the infusorial earth, which is incombustible, but in No. 2 Neptune, Vigorite, Vulcan, &c., the nitro-glycerine explosion produces high heat, which burns up the combustible absorbent. Any pulverized combustible would be consumed in like manner. Sawdust, charcoal, dried paper pulp, rosin, paraffine,

pitch and other carbons or hydrocarbons which have been used in making No. 2 are all completely consumed, just as is the Vulcan absorbent."

Robert J. Howe, a dealer in powder and various explosives, and formerly foreman of the Laflin Powder Company's mills, testified for the defendants in the Neptune Powder Company case as follows:

"Neptune powder compound, before adding nitro-glycerine, is in the form of powder dust, and is an explosive in itself. If ten per cent., or any greater proportion of nitro-glycerine which it can retain, is added to it, the resulting compound is explosive, while infusorial earth must contain over thirty per cent. of nitro-glycerine to explode at all, and a much larger proportion to make an effective explosive. Grained gunpowder, mealed gunpowder, gunpowder dust or Neptune compound will not take up and retain more than about thirty per cent. Difference in temperature makes a difference in the retentive power of the substances. They will retain more in cold weather than in warm. My experience teaches me that about thirty per cent. of nitro-glycerine is the quantity they can be relied upon in practice to retain. Dry pulverized nitrate of soda will not take up and retain thirty per cent. of nitro-glycerine, but only about fifteen per cent. It might be made to retain, under certain conditions of temperature, twenty per cent., but when thirty per cent. is added to it it slowly trickles from it, and upon being squeezed in the hand it is discharged between the fingers.

"A mixture of 70 parts of either infusorial earth, charcoal or sawdust with 30 parts of nitro-glycerine is inexplosive, yet either of the following mixtures are explosive—

Nitrate of soda	75	or	40 parts.
Charcoal	10		"
Nitro-glycerine	15	15	"
Sawdust		20	"

Also these are explosive—

Gunpowder dust	90	parts.
Neptune compound		90 "
Nitro-glycerine	10	10 "

"The nitro-glycerine does receive explosive aid from the Neptune compound, from gunpowder, from gunpowder dust and from a mixture of sawdust and nitrate of soda. It is a well-known fact that

gunpowder is more effective when exploded by percussion caps than by simple fuse. Some consumers (contractors) always use percussion caps for that purpose. For the same reason, caps are better to explode Neptune powder, but Neptune powder is largely used by some parties and exploded (without cap) by fuse alone. In such use the powder of the Neptune powder explodes the nitro-glycerine of the Neptune powder in the same manner as indicated in the patent to Nobel, No. 50,617, filed 10th May, 1865."

Dr. Henry Morton, President of the Stevens Institute, testified "That while at North Adams, in December, 1875, I mixed 52 parts of nitro-glycerine with 48 parts of infusorial earth sent me by the complainants, and made this into a cartridge of the usual form, and inserted in this an 'exploder' or cap containing 16 grains of fulminating mercury. When this was fired in the usual way the cartridge did not explode. I then placed another 'exploder' or cap containing 22 grains of the fulminate in the cartridge, and enclosed the whole in a short wrought-iron tube, tamping the ends with sand. On firing this 'exploder' the iron tube was split open by the force of its explosion, but the mixture of infusorial earth and nitro-glycerine remained unaffected as before. I am, therefore, quite certain that a mixture of infusorial earth and nitro-glycerine in the proportions found by Dr. Hayes between the gunpowder and nitro-glycerine in the explosive compound* of defendants, would be totally inexplodible."

Prof. Morton then goes on to show that using various devices for increasing the explosive force of gunpowder is no new thing and cites the following: "In the *Chemical News*, London, July 6, 1866, on p. 16, he finds as follows: Some experiments were in the first instance made with gunpowder the grains of which had been saturated with nitro-glycerine. This powder burned much as usual, but with a brighter flame in open air. When confined in shells or blast holes, greater effects were, however, produced with it than with ordinary gunpowder; its destructive action is described as having been from three to six times greater than that of powder.

"The same account is published in the *Proceedings of the Royal Institution*, Vol. IV, p. 621, London, 1866. It is also published in the *Journal of the Franklin Institute*, Philadelphia, 1866, Vol. 52, p. 275.

"This deponent further says, that the increasing of the explosive force of gunpowder by the admixture of various bodies with it has

* Neptune powder.

been from time to time practiced from the early part of this century; thus, in the *Encyclopædia Britannica*, Edinburgh, 1815, is found an account of experiments made by Count Rumford. He used oil of turpentine, quicksilver, salt of tartar, sal ammoniac and brass filings, with this object. In *Cutbush's Pyrotechny*, Philadelphia, 1825, p. 140, we find: Quicklime is said to increase the force of powder. Dr. Baine says that three ounces of pulverized quicklime being added to one pound of gunpowder, its force will be augmented one-third. M. Vergnaud, in a work on fulminating powders in 1846, asserts that certain rifle powder consisted of gunpowder mixed with fulminate of mercury. In the *Mechanics Magazine*, London, 1825, Vol. 3, p. 275, we find a description of experiments with powder mixed with oil, which showed an increase of effect. In *Ure's Dictionary*, New York, 1853, p. 174, we find admixture of sawdust with gunpowder recommended as increasing its explosive force. In the *London Artizan* of 1862 we have a description of Mr. Bennet's improved blasting powder, which consisted of a mixture in which lime was added to the usual ingredient of gunpowder. In the *American Repertory*, New York, 1841, Mr. Mayer proposes admixture of rosin with gunpowder to increase its effect in blasting."

The injunctions against the manufacturers of Neptune and Vulcan powders were granted. The value of this monopoly may be shown as follows: It is claimed that with proper exploders a dynamite composed of 30 per cent. nitro-glycerine and 70 per cent. meal powder will do as much work as a dynamite composed of 75 per cent. of nitro-glycerine and 25 per cent. of infusorial silica. The difference in cost may be estimated as follows:

Vulcan Powder.

70 lbs. of meal powder, @ .04	. . . . .	\$ 2.80
30 " nitro-glycerine, @ .40	. . . . .	12.00
<hr/>		<hr/>
100 lbs. of powder cost .	. . . . .	\$14.80

Dynamite No. 1.

25 lbs. of infusorial silica, @ .03	. . . . .	.75
75 " nitro-glycerine, @ .40	. . . . .	30.00
<hr/>		<hr/>
100 lbs. of dynamite cost	. . . . .	\$30.75

In a previous suit Judge Blatchford issued an injunction against the manufacture of the following powders :

	No. 1.	No. 2.
Nitro-glycerine	67.64	27.86
Cellulose (paper stock)	16.82 (sawdust and charcoal)	5.59
Nitrate of soda	15.54	66.55

The Popular Science News, James R. Nichols, M. D., editor, 17, 53, May 1883, contains an editorial article entitled, "What is Dynamite?" from which we extract the following as being a good example of popular science. Referring to the recent difficulties in England, Russia, Spain and elsewhere in Europe, it says: "In dynamite we have a pasty black mass, almost perfectly safe to handle, of which enough can be carried in a side pocket to destroy the lives of a hundred men, if favorably situated, or shatter a building nearly as effectively as could be done with half a barrel of gunpowder placed under it.

"What is dynamite? How is it manufactured? We are fully prepared to answer these questions, as we manufactured the first nitro-glycerine ever made in the United States, nearly twenty years ago, and have had some experiences with it not pleasant to recall. Dynamite is simply nitro-glycerine mixed with an adulterant to render it safe to transport. The added ingredient is usually a fine earth of great absorbent capacity. It has been found that the best kind is the earth which good housewives use to polish their silver with, properly called *infusorial* earth, because it is made up of the fossil remains of minute organisms. Dynamite, then, is a mixture of innocent polishing powder and sweet, bland glycerine, after it has been acted upon by nitric acid. There is nothing apparently very frightful in this mixture. We can eat glycerine on our puddings and griddle-cakes and grow fat upon it; and a box of silver polish in the house is as harmless as a cake of soap.

"In what has been stated, a strange law of chemical combination comes into view, a law by which a vast change is produced in innocent bodies by a slight disturbance of their molecular constitution. We disturb the molecular constitution of glycerine by subjecting it to the action of nitric acid, by which nitrogen becomes a constituent of the body, and its whole chemical nature and relationship are changed.

“The dull, stupid nitrogen which exists so abundantly in the air, and which we breathe into our lungs every moment, day and night, becomes the agent which confers upon glycerine the most terrific powers possessed by any agent, save two, known to man. Does not this fact teach an impressive lesson as to the mystery of the forces of nature, and of man’s capability of bringing them into action, and we may say, into subjection? If such facts do not cause a feeling of respect for chemical science, it is difficult to conceive of any that will.

“In the manufacture of nitro-glycerine we simply mix with pure glycerine a certain proportion of sulphuric and nitric acids and stir the mixture until the reactions occur, which is in about twenty minutes. The vessels must be placed in freezing mixtures, for if at any time the temperature rises above 32° F. decomposition occurs, and if there is no explosion the whole mass goes off in a vast cloud of nitrous acid vapors which are troublesome and dangerous.

“We never ventured to act upon more than one hundred grains of glycerine at a time, and with this small amount the danger was great and accidents were not a few.

“Our method was to arrange upon a shelf, in a refrigerating mixture, twelve beaker glasses, each containing one hundred grains of glycerine, and into each of them the mixed acids were slowly allowed to enter, the thermometer being anxiously watched all the time. If the heat from the reactions rose above 32° in any glass, away would go the contents, filling the laboratory so densely with red fumes that no object could be seen six feet distant.

“It was regarded as a successful experiment if we saved four glasses out of the dozen. Whilst at present the methods of production are not different, the apparatus and appliances are greatly improved. It must be remembered that we were pioneers in the dangerous manufacture, and but little of the product was needed in medicine and the arts. Now the consumption is enormous, and large manufactories are established in many sections of the country. The United States government chemists make the best nitro-glycerine at the laboratory at Newport, Rhode Island. It is used largely for filling torpedoes.

“In what has been said we have endeavored to afford a popular view of the chemistry of dynamite. It does not explode at the touch of fire, as does gunpowder, but it must have brought to bear upon it, or in contact with it, another explosive agent, a *fulminate*. A fulminate of mercury is better than a fulminate of silver, for the *rhythm* of

its detonation is more in accord with that of dynamite. Dynamite *detonates*, and does not explode as does gunpowder. Its action is so much quicker than the movement of air that it strikes against a column of air with the same force as a hammer falling upon a blacksmith's anvil."

The following books may be of interest to students of explosives :
Die Grundsätze der Thermochemie. Dr. Hans Jahn. Vienna, 1882. Alfred Holder, 8vo, 238 pp.

Thermochemische Untersuchungen. Julius Thomsen. Vol. I. Neutralization und verwandte Phenomena, 449 pp. Vol. II. Metalloide, 506 pp. Leipzig, 1882. J. A. Barth.

Lehr- und Handbuch der Thermochemie. Dr. Alex. Naumann. Brunswick, 1882, F. Vieweg und Sohn. 606 pp.

The Explosive Art, 1875, and the Orders in Council of April 20, 1883, their Prejudicial Effect on Mining and Quarrying, and the Encouragement they give to Fenians. London, 1883, A. P. Blundell & Co.

NAVAL INSTITUTE, ANNAPOLIS, MD.

FEBRUARY, 1885.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

PROF. CHARLES E. MUNROE, U. S. N. A.

No. VII.

Through the courtesy of Col. V. D. Majendie, C. B., H. M. Chief Inspector of Explosives, we are in receipt of the *Seventh Annual Report* (1882) of *H. M. Inspectors of Explosives*, and of several special reports of the circumstances attending some recent cases of explosion. The number of factories (exclusive of "toy" fireworks factories) is now one hundred. The following explosives have been added to the licensed list:

E. C. Sporting Powder.† Consisting of rifle gun-cotton, with the addition of coloring matter consisting of aurine (free from mineral acid) dissolved in a solvent composed of ether, alcohol and benzoline.

E. C. Rifle Powder. Consisting of rifle gun-cotton, with the addition of coloring matter consisting of picric acid (free from mineral acid) dissolved in a solvent composed of ether, alcohol and benzoline.

Asphaline No. 1. Consisting of a mixture of chlorate of potash and bran, as hereinafter defined, with or without an admixture of one or more of the following ingredients, viz. nitrate of potassium, sulphate of potassium, paraffin oil, paraffin, ozokerit (such paraffin oil, paraffin and ozokerit to be free from mineral acid), soap, fuchsine; such mixture to contain not more than 54 parts, by weight, of chlorate of potassium, and four parts, by weight, of nitrate of potassium and sulphate of potassium, or either of them, to every 42 parts, by weight, of bran.

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars.

† These Notes, 10, 221.

Bran, consisting of wheat bran or barley bran, thoroughly cleansed and reasonably free from flour.

Asphaline No. 2. Consisting of asphaline No. 1, as above described, with the addition of nitrate of potassium in such proportion that the total amount of nitrate of potassium present shall not exceed 25 parts, by weight, in 100 parts, by weight, of the finished explosive.

Spon's Electric Fuses. Consisting of a case of metal, wood, paper or other suitable material, containing two or more insulated wires, the terminals of which are (a) imbedded in a charge not exceeding five grains of one or other of the priming compositions (1) (2) (3) hereinafter specified, or (b) connected by a bridge of fine wire, composed of a platinum alloy, steel or other suitable material, the said bridge being imbedded in a charge not exceeding ten grains of one or other of the priming compositions (4) (5) hereinafter mentioned.

Priming composition (1), chlorate of potash and sulphide of antimony, with or without powdered carbon.

Priming composition (2), chlorate of potash, sulphide of antimony and phosphide of copper.

Priming composition (3), chlorate of potash, sulphide of copper and phosphide of copper.

Priming composition (4), gun-cotton thoroughly purified.

Priming composition (5), gun-cotton thoroughly purified, chlorate of potash and powdered galls.

Spon's Electric Detonator Fuses. Consisting of electric fuses, as above described, and having attached thereto a detonator, as defined by an Order in Council made under the 106th section of the Act.

Hunter's Patent Miners' Fuses. Consisting of a cylindrical tube of paper, varnished or coated with a suitable waterproof solution, and filled with gunpowder, in the proportion of not more than one pound of gunpowder to every five hundred fuses, the paper tube being closed at both ends, and having one end primed with a solution of nitrate of potassium or nitrate of sodium, or with melted sulphur, with or without nitrate of potassium.

Miners' Squibs. Consisting of a tube of paper, or other suitable material, partly filled with gunpowder in the proportion of not more than one pound of gunpowder to every five hundred squibs, and having one end closed with a plug of wax, or other suitable material, and the other end closed by being twisted, and such twisted end being coated with sulphur or not so coated.

Sound Signal Rockets. Consisting of a signal rocket having fitted

in the head thereof one or more charges of tonite * or cotton powder as hereinafter described, and with or without a layer of compressed gunpowder made of sulphur (free from acid), saltpetre, and charcoal, between the said charges, and having imbedded in the said charges one or more detonators as defined by an Order in Council, made under the 106th section of the Act, such detonators to contain above the fulminate a substantial layer either of strongly compressed mealed gunpowder or of a composition made of two or more of the following ingredients, viz. saltpetre, sulphur (carefully washed), realgar, antimony, gunpowder. The said tonite to consist of gun-cotton thoroughly purified, mixed, or incorporated with a nitrate or nitrates.

Distress Signal Rockets. Consisting of sound signal rockets as above described, with the addition in the head of the rocket of one or more stars composed of two or more of the following ingredients, viz. saltpetre, sulphur (carefully washed), realgar, antimony, gunpowder.

The name of the explosive designated as *Liverpool Cotton Powder* or *Potentite* was changed first to *Potentite Cotton Powder*, and subsequently to *Potentite*. Potentite (which is nitrated gun-cotton) is manufactured by the Potentite Co., at Melling. Certain specimens of their product were found to be so impure that they were warned.

The importance of putting dynamite in waterproof envelopes, for transportation, is illustrated in the case of the sinking of a barge, where the water reached the dynamite and expelled the nitro-glycerine. Again, in 1882, a case of dynamite was being conveyed across the Duddon Sands. The driver of the cart, trying to make a short cut, got into a quicksand, when the water reached the dynamite and caused the exudation of a large quantity of nitro-glycerine.

A new illustration of the failure of prohibition to prohibit is the following: The railway companies have refused to carry dynamite and some other explosives of that class under any conditions, notwithstanding the remonstrances of the Inspectors of Explosives. Hence it is not surprising to learn that an agent of the Nobel's Explosive Co. was found to have carried no less than 300 lbs. of blasting gelatine on a passenger train from Newcastle to London, across London in a cab, and thence by rail to Whitstable. The explosive was packed in soft leather bags, a portion of them being taken in a smoking-car, and the rest as ordinary passenger luggage in the van.

* These Notes 9, 754.

The importations of dynamite for the year amounted to 1,008,050 lbs. With two exceptions this dynamite satisfied the required tests. The first was a cargo of 22,200 lbs., from Krebs & Co., of Cologne, made from very imperfectly purified nitro-glycerine. The second, of 75,000 lbs., from Nobel's Explosive Co., Hamburg, was made of nitro-glycerine of satisfactory purity, but the kieselguhr was strongly and dangerously acid. An importation of "Forcite" from Spain was prevented, as examination showed it to be an explosive which had never been examined or tested in England, and of whose properties the inspectors were ignorant. The importation of fulminate of mercury amounted to 12,400 lbs., and of detonators to 1,075,000 lbs.

The report of Dr. Dupré, chemist, to the Home Office, shows that the blasting gelatine submitted to him was in every case rejected, as showing a tendency to exude nitro-glycerine, while in addition, in some cases, the cartridges were of a soft or semi-fluid character, which became very marked at 80° F., thus defeating the *main* object of its manufacture, namely, the conversion of a *liquid too dangerous* to use on *account* of its being a *liquid* into a *solid*, comparatively safe explosive, *safe because* it is *solid*.

Samples of colored fires and fireworks were examined, owing to an accident at Stoke, and it is stated that the presence of sulphur in a chlorate mixture, even when the sulphur has been carefully washed, is a source of danger. Mixtures containing sulphur and a chlorate are exceedingly sensitive to percussion and friction. It is recommended that potassium perchlorate be substituted for the chlorate, as suggested by a German periodical. The sensitiveness to percussion and friction is thus diminished while the brilliancy is increased. Experiment showed that a one-pound weight falling 10 to 12 inches exploded a mixture of potassium chlorate and sulphur, while a fall of the same weight through 18 to 20 inches was required to explode a similar mixture of perchlorate. Moreover, while the chlorate mixture exploded completely at the first or second blow, it required from five to seven blows to entirely explode the perchlorate mixture. The substitution of the perchlorate would also, probably, diminish the danger of spontaneous ignition of sulphur mixtures, since not even oil of vitriol decomposes perchloric acid.

Experiments made with mixtures of filings or borings of iron or steel, with sulphur, showed that when moistened with water and surrounded by bad conductors of heat, or in insufficient mass, the temperature rose rapidly, much steam was evolved and the mixture

became in some cases red hot. This would seem to show that Gerbe mixtures were liable to spontaneous ignition, but in fact the danger is believed to be slight, since the iron borings used are generally very coarse, and since charcoal and nitre are also added. The points of contact of iron and sulphur are therefore limited, in consequence of which the amount of chemical action which can take place in a given time is but small, and but little heat is evolved. In several experiments with recently made Gerbe mixtures the maximum elevation after moistening was 5° F. When, however, the coarse iron borings were extracted from this mixture by a magnet, and replaced by an equal weight of fine filings, the temperature rose in a few hours as much as 45° F. This would not be enough to endanger the stability of the mixture, but would seriously endanger the safety of a star of sulphur and a chlorate imbedded in it. Iron filings and nitre when moistened likewise increased in temperature with oxidation of the iron and reduction of the nitrate to nitrite. The action, though beginning very soon, is far from energetic, and the rise in temperature is only 5° F.

The influence of temperature on the sensitiveness of dynamite to percussion was tested, showing, as was to be expected, that warm dynamite was more sensitive than cold. One grain of dynamite, at a temperature of 60° F., required a fall of a one-pound steel weight through 18 inches to explode it, while similar quantities at a temperature of 200° F. were exploded by the same weight falling through 9 inches. Similar differences had previously been found with gun-cotton and Schultze gunpowder.

In analyzing an impure nitro-cellulose, the insoluble residue, after extraction with alcohol and ether, exploded spontaneously, while drying in the water oven.

Experiments on the inflammability of moistened tonite showed that with 8 per cent. of moisture tonite could be set fire to and would continue to burn. With 10 to 11 per cent. it is unflammable. This is considerably less than is necessary for pure gun-cotton, which requires from 18 to 20 per cent.

Two new explosives were examined—asphaline (given above) and virite. Of the latter there were two kinds. Virite No. 1, a mixture of nitro-glycerine, potassium nitrate and charcoal, passed all the tests successfully. Virite No. 2, containing sodium nitrate in place of potassium nitrate, failed to hold the nitro-glycerine under all the conditions of the tests.

This report contains an admirable summary of the accidental and intentional explosions which have occurred during the year, and much other information to be referred to hereafter.

Special Report No. 48, January 19th, 1883, by Colonel V. D. Majendie, is "On Two Explosions at the Factory of the Explosives Company (Limited), at Pembrey Burrows, Carmarthenshire." The license for this company was granted July 25th, 1882, after the factory had been previously inspected by Colonel Majendie and Captain Cundill. The process employed for making the nitro-glycerine was that invented by Boutmy, and which has been in operation at Vonges since 1872. The license permitted the nitrating of 1500 lbs. of glycerine at one charge. The first explosion took place on the 11th of November, 1882, in the converter. The nitration had been started the day before, and at the time of the accident all but 500 or 600 lbs. of the nitro-glycerine had been removed. The men then drew off the acid until the remaining nitro-glycerine reached the lower tap. Several vessels of this nitro-glycerine were then drawn off, and while the men were busy storing these vessels in another room, the nitro-glycerine left in the converter exploded. It was stated by a workman, who left the building about five minutes before the explosion, that the fumes from the nitro-glycerine were quite exceptional, and that they had nearly choked him as he drew it off. Colonel Majendie finds the cause to be due to violent chemical action established through the decomposition of the nitro-glycerine by the acid present, and cites several previous cases of explosion believed to be due to the same cause. It is noticeable, however, that in all the cases cited, where details are given, it is shown that the action was superinduced by foreign matter, such as water, straw and the like, coming in contact with the acid mixture, and in the case under consideration the apparatus was so constructed that it was possible for foreign matter to get into the converter. In addition Dr. Dupré reports that the glycerine used at Pembrey was impure and not well adapted for the manufacture of nitro-glycerine. It had a rather dark color, a feebly acid reaction, and gave a strong precipitate with nitrate of silver. When mixed with strong sulphuric acid it became very dark and evolved a disagreeable odor. It contained:

Fatty acids about	. . . .	0.5	per cent.
Fat	. . . . .	0.3	"
Chlorine in form of chlorides,		0.15	"
Water	. . . . .	5.00	"

Besides, no precautions were taken to secure nitric acid free from nitrous acid. While the presence of strong acid will cause the decomposition of pure nitro-glycerine, as has long since been pointed out, it does not seem necessary to look for other causes when we find, as in this case, that the materials employed in the manufacture were impure.

After describing the Boutny process as used at Vonges, Colonel Majendie states that it "will be found more fully and elaborately explained" in the *Proc. United States Naval Institute*, 5, 5, 1879. In criticising, however, our omitting to point out the weaknesses of the process, he mistakes a narration for advocacy, and overlooks the fact that the source of the information is quoted.

The second explosion at Pembrey occurred during the thawing of frozen dynamite; and while the cause is obscure, it is thought to have been due to the falling of a zinc scoop or zinc tray into a metal-lined box containing dynamite, which was probably warmed from the thawing process. Seven persons were killed and one wounded in this explosion, while no one was injured in the first explosion.

Special Report No. 55 is by Colonel Majendie and Captain Cundill, and describes the "Circumstances attending Two Explosions which occurred on the Underground Railway, London, on the 30th October, 1883." These explosions took place near the Praed Street Station and at a point between the Charing Cross and Westminster Stations. The first explosion occurred in a tunnel, about 138 feet distant from the station, as the 7.52 P. M. train was passing. The damage in the tunnel consisted in a vertical crater in the wall about 12 inches high, 13 inches wide and 4 to 6 inches deep. Immediately below this crater and extending about 15 inches along the wall, was a horizontal crater about 6 inches deep, partly in the ballast and partly in the brick footing of the tunnel. The flinty ballast in this crater was considerably splintered and the brick footing pulverized. A two-inch gas pipe ran along the wall at a height of 10 inches; a length of this, measuring 14 feet, was blown away, one end being much torn and twisted, and the whole piece bent into the form of a bow. At a distance of 15 inches from the wall, and parallel with it, was an iron switch-rod consisting of a $1\frac{1}{4}$ inch gas pipe supported on iron rollers at the level of the rails, from which it was distant 2 feet 9 inches, the rollers being fixed on a wooden plank laid on the ballast. The board had about 4 feet of its length blown to splinters, and a large piece thrown upon

the rail, and some of the wheels of the train passed over it. A length of the switch-rod, measuring about two feet, and corresponding exactly with the portion of the gas pipe which sustained the maximum injury, was blown out, the central part of this detached portion being split up and torn. This piece of switch-rod also bore marks of the wheels upon it. A telegraph cable running along the wall at the height of $8\frac{1}{2}$ feet was cut by the explosion. The walls of the tunnel were scored somewhat by the sharp debris blown against them, and the end of a sleeper opposite the crater, but partially protected by the ballast in which it was imbedded, had a number of pieces of splintered stone driven deeply into it. The rails were entirely uninjured.

The injury to the passing train was confined principally to the two last carriages of the six composing the train. In these the greater part of the glass was broken into small fragments, panels and partitions were shattered, the roofs and floors disturbed, the footboards broken, and the carriages seemed to be completely wrecked, yet no part of the framing or running gear was injured.

The gas throughout the train was extinguished, yet the apparatus was found to be uninjured. It is interesting to note that the injury to the train was not confined to the side on which the explosion took place, but extended also to the opposite side, and in the case of one carriage the damage was most marked on that side; 62 persons were injured by cuts and contusions from the pieces of glass and debris, and in one or two cases by *fracture of the drum of the ear* and by severe shocks. Five of the injured were confined in the hospital for a considerable time. The breaking of the glass and putting out of the gas occurred on the surface at the openings of the tunnel for a distance of 350 feet.

The second explosion, which occurred almost simultaneously with the first, took place at a point 24 yards from Charing Cross and 488 yards from Westminster. As it occurred opposite a bay, the only damage done was the breaking of glass and the extinction of gas in both stations; the injuring of the telegraph and telephone wires for about 60 yards; the formation of a crater in the ballast, measuring 3 x 4 inches wide and 1 inch deep; and the "patting" of the walls of the tunnel on the side of the explosion for some little distance to the right and left of the crater, and on the opposite side for a somewhat greater distance. The rails were entirely uninjured, but the ends of the sleepers near to which the explosion occurred sustained some injury.

Three hypotheses were suggested as to the nature of the explosive, viz. coal gas, gunpowder and dynamite. The fact that all the gas apparatus was found intact disposed of the first; the absence of all residue and the extremely local and brusque action of the explosion testified unmistakably to the use of an agent possessing greater detonative energy than gunpowder, while these properties are characteristic of dynamite. The finding a piece of Bickford safety fuse and fragments of copper, presumably from a detonator, strengthened this belief. Accepting this theory, experiments were made by Colonel Majendie, together with Professor Abel and Dr. Dupré, to determine the amount of dynamite necessary to produce the observed effects, the switch-rod and gas pipe from the Praed Street tunnel being used in similar positions to the charge which they bore there, and it was found that two pounds of ordinary dynamite would be sufficient, if properly detonated. The circumstances surrounding the explosions, however, indicated that a larger amount, probably five pounds, had been used, but that a portion had burned without explosion.

The explosion was probably induced by the use of a fuse of such a length as would burn for the desired time. This was then attached to a detonating cap and the latter inserted in a zinc case containing the dynamite. The assassin then boarded a passing train, and lighting the fuse threw the contrivance from the window, the fuse being timed to explode the cartridge under the train following. In the case of the Praed Street train the explosion was premature, and occurred under the train in which the assassin was. In the second case the explosion occurred at the time designed, but the train for which it was intended was late; in one minute more the train would have reached the spot.

In manufacturing processes in chemistry considerable loss ensues where the process must be arrested from time to time in order to permit of the charging or discharging of the apparatus; hence efforts are constantly being made to devise apparatuses and methods by which the processes may go on continuously. Such a method has now been invented by W. N. Hill, for the manufacture of nitro-glycerine, and for which *U. S. Letters Patent No. 262,769* have been issued. Without the aid of drawings it is difficult to describe the apparatus, but it will suffice to say that it consists of two converters, with acid and glycerine tanks attached, a separator and receivers for the nitro-glycerine and spent acids, all connected by tubes so that the

contents of one may flow to the other. The use of two converters admits of the conversion taking place by successive stages, while weaker acid may be used in the earlier stage. The separator is so arranged as to help materially in controlling the speed of the operation, while by the position of the receivers relatively to the separator we can easily see how the process is progressing at any given time. Of course proper arrangements are made for promoting the mixing of the ingredients and cooling of the mixtures.

Mr. George M'Roberts, F. C. S., has favored us with a copy of an excellent resumé presented by him to the Philosophical Society of Glasgow, April 25th, 1883, under the title "Notes on Nitro-glycerine, Dynamite and Blasting Gelatine," from which we learn that at low temperatures blasting gelatine freezes into a hard whitish solid of crystalline structure; but the exact temperature at which freezing takes place has not been ascertained, as cartridges are sometimes found to resist freezing for 24 hours, although kept during that time in a mixture of ice and salt. Other cartridges are found to freeze readily at about 35° to 40° F. Frozen gelatine is in some respects more easily exploded than unfrozen gelatine. A rifle bullet can be fired through any number of unfrozen gelatine cartridges without exploding them, but when a shot is fired similarly through frozen cartridges they never failed to go off. In this respect blasting gelatine behaves exactly the reverse of dynamite. The transmission of detonation through blasting gelatine when unfrozen is much more slow than through either nitro-glycerine or dynamite, but when the cartridges are frozen the detonation appears to be quite as rapid as in dynamite. It has been lately sought to use blasting gelatine in shells, but the material in its present form does not appear to be well adapted to such a purpose. In order to render it less sensitive, so that the shell might be fired from the gun without risk of exploding the charge, the gelatine had incorporated with it about 3 to 5 per cent. of camphor. The camphor had the effect of rendering the gelatine so insensible to shock that even the blow of the shell against an iron target failed to set it off, and the gelatine was gathered up in bits all around the target. The effect of increasing the proportion of nitro-cotton in gelatine, and diminishing that of nitro-glycerine, is to lessen its sensibility to explosion; and gelatine made tough with 9 or 10 per cent. of nitro-cotton cannot be got to explode with a detonator containing 12 grains of fulminate of mercury and chlorate of potassium.

On the other hand, when gelatine is made of a viscid consistency—such that a cartridge, when deprived of its wrapper and allowed to stand on a porcelain plate, begins to spread itself out—the ordinary detonator in use for exploding dynamite never fails to explode it.

When 10 grams of explosive were fired, with a fuse and detonator, in a pendulum mortar, the following results were obtained :

	Foot pounds.
Blasting gelatine, consisting of 93 per cent. of nitro-glycerine and 7 per cent. of nitro-cotton,	1400
Nitro-glycerine,	1270
No. 1 Dynamite,	900
No. 2 Dynamite consisting of 18 parts of nitro-glycerine, 71 parts of nitrate of potash, 10 parts of charcoal, and one part of paraffin,	531
Westquarter factory mixture for detonators, consisting of 70 parts fulminate of mercury and 30 parts KClO_3 , .	481
Gun-cotton,*	462
Fulminate of mercury,	307
Curtis and Harvey's extra strong gunpowder,	272

The method of testing explosives described above is applicable only to those that detonate, or, in other words, to those explosives whose conversion into gas is practically instantaneous. If the explosive is a slow one, such as gunpowder, the projectile may have escaped before the whole charge is consumed; but with detonating mixtures the explosion is so rapid that there can be no doubt that the conversion into gas is complete, even before the projectile has begun to move. The chronoscope of Captain Noble showed that explosion is transmitted through trains of dynamite at the rate of 20,000 to 24,000 feet per second. At this rate the explosion of a cartridge a foot long must only occupy the 24,000th part of a second. A ton of dynamite cartridges of the usual size, about $\frac{7}{8}$ " diameter, laid end to end in a line would stretch a mile, and the whole train could be exploded in the one-fourth part of a second by firing a cartridge at either of the ends. If fired in the middle of the line the explosion would be transmitted both ways, and would occupy only the eighth part of a second. The facility with which dynamite can be fired in trains offers great advantage in many engineering operations, such as where it is

* The reason, no doubt, why the gun-cotton shows so poorly in this table is that its explosion in the mortar was imperfect.

required to blow down an arch or a wall. It is enough to lay a train of cartridges along the crown of the arch, or along the bottom of the wall, and explode one cartridge in the usual way with a detonator. The whole train goes off instantly. The enormous velocity with which dynamite explodes explains the great violence of its action, and the tremendous local rupturing effects of even small quantities of it exploded in the open, and without being enclosed in a case of any kind. The detonation of a cartridge in the 24,000th part of a second must produce an enormous instantaneous pressure on the spot on which it explodes. For such a sudden explosion the pressure of the atmosphere itself is sufficient tamping.

The increase in the demand among miners for strong explosives is very remarkable. Since 1867 the annual sales of dynamite from the factories with which Mr. Nobel is associated have been as follows:

In 1867,	11 tons.	In 1875,	3500 tons.
1868,	78	1876,	4300
1869,	184	1877,	5500
1870,	424	1878,	6200
1871,	785	1879,	7000
1872,	1350	1880,	7500
1873,	2050	1881,	8500
1874,	3120	1882,	9500

The last two years have been estimated, as there are no precise figures to go by. The sale of such a large quantity of explosives indicates a considerable amount of mining activity. Besides the factories with which Mr. Nobel is connected, numerous others have sprung into existence, notably in Germany and in America. In Austria dynamite is no longer manufactured, as there is no demand for it, its place having been taken by blasting gelatine.

It is unfortunate that in Great Britain the manufacture and sale of explosives is hampered to a hurtful degree by legislative restrictions. Some restriction is no doubt necessary, but in this country restriction amounts in some cases almost to prohibition, if a new explosive is to be introduced. As the law now stands, if a manufacturer discovers a new explosive or a new explosive mixture, he cannot make working trials of it without the consent of the Home Office, and without having submitted samples for the approval of the Home Office Chemist, to whom, as a matter of course, a fee must be paid. This regulation must interfere with the introduction of a new invention, because no

man will care to pay fees for the examination of an explosive which, when it comes to be tried, may not take with the public after all. Abroad, although there are restrictions affecting explosives, there are no such onerous impediments as here; hence foreign chemists and manufacturers have an advantage in that respect.

The Pennsylvania Railroad Company has issued the following rules concerning the transportation of explosives over its system of lines:

High explosives such as Atlas, Hercules, Giant, Dittmar, Commercial, Ætna, Hecla, and other nitro-glycerine powders, will be received for shipment only under the following conditions:

First. Shipments to be packed in strong boxes, not too large to be readily handled by one person, and each package to be plainly marked "Explosives"—"Dangerous" on top, and on one side or on one end.

Second. It is understood that in these articles the nitro-glycerine is thoroughly absorbed in charcoal, sawdust, infusorial earth, wood fibre, carbonate of magnesia, or other similar substances, and that the amount of nitro-glycerine is such that the temperature of the hottest summer day will not occasion a leakage. Should any package show outward signs of any oily stain, or other indication that absorption is not perfect, or that the amount of nitro-glycerine is greater than the absorbent can carry, the packages must be refused in every instance, and must not be allowed to remain on the property of the company.

Third. Nitrate or other explosive preparations not in accordance with above specifications (except ordinary black powder) will in no case be received for shipment.

Fourth. Shipments must be loaded so as to lie bottom side down, it being understood that the cartridges are so placed in the boxes that they will lie on their sides, and never on their ends when so loaded. The boxes must be so placed in car that they cannot fall to the floor under any circumstances.

Fifth. Shipments of common black powder may be received if packed in good substantial iron or wood kegs. Packages not to exceed one hundred and fifty pounds in weight, unless for export, when larger packages will be received.

Sixth. In no case will percussion caps, exploders, safety squibs, fulminators, friction matches, or any other articles of like nature be loaded in same car with any of the above explosives. There cannot be too great care exercised in this matter.

Seventh. Safety fuse will be received for shipment at any time it is offered, and the restrictions in regard to shipping powder do not apply to it.

Eighth. As the special powder cars will be taken out of this service, agents must know that none of the above explosive substances are loaded at their stations in old cars having loose boards or cracks in the roof or sides. Cars for carrying these explosives must be first-class in every respect, must be tight everywhere, and must have doors that can be closely shut, leaving no crack for sparks to get in. When in full carloads the doors must be stripped.

Ninth. Every car containing any of the above explosive substances, either full carload or small package, must be plainly marked on both sides, "Powder—Handle Carefully," so that those having charge of it will not do anything ignorantly to incur danger. This should be done by the shipper of full carloads and by the agent when the packages are loaded in car at his station.

Tenth. Conductors must not take from any station or siding any car known to contain an explosive substance, unless Rules 8 and 9 have been complied with, and such cars must be placed in their train as near the middle as possible.

The law provides heavy penalties, both to shippers and common carriers, for violation of these rules, and agents should be careful to see that such shipments are put up, marked and forwarded only under their proper names, and in accordance with these provisions.

The *Iron Era*, of Dover, New Jersey, December 22, 1883, contains an account of the opening of the works of the American Forcite Powder Manufacturing Company at Lake Hopatcong on the Morris Canal. The works number upwards of forty buildings covering an area of 450 acres of land, heavily wooded. The buildings, where the powder manufacturing is to be done, are situated from 100 to 200 feet apart, and placed in excavations in the side-hills so that only one side is exposed. All these buildings are lined, ceiled, heated by steam and furnished with water. The nitro-glycerine is carried from the converting house to the mixing house, by gravity, through large India-rubber pipes, well protected and laid under the ground. The converting house is a three-story frame building 32 x 32 feet. The converter is in the third story, the separating tanks and washing tanks are on the lower floors. The spent acid flows through leaden pipes to the acid house, where it is regenerated and forced back to

the converting house 900 feet away. The acid house is of brick, 25 x 65 feet, and contains four large retorts and condensing towers for regenerating the spent acids. The magazines are built in excavations in the hill so that the roofs are below the surface of the ground. The structures are of brick with roofs of corrugated iron. This roof forms a lightning conductor and has rods leading from the four corners into the ground, as in the Belgian government magazines. A system of ventilation, through hollow bricks, allows the air to enter at the bottom and escape at the top. A reservoir capable of furnishing 60,000 gallons of water daily, and an ice house 30 x 50 feet are connected with the works. The concern has a capacity of five tons of powder per day, and beginning with a force of 50 men it is expected to soon increase to 100.

Forcite is described as a hard plastic substance looking very much like India-rubber and as tough. The principal advantages claimed for it are greater safety in handling than other nitro-glycerine compounds possess, and imperviousness to water. It may be exposed to a temperature of 120° without allowing the nitro-glycerine to exude, and may be submerged under water a long time without damage. There are now three factories in Europe making this powder.

U. S. Letters Patent No. 242,783, dated June 14, 1881, and granted to John M. Lewin, of Paris, France, describe "Forcite" and the method of preparing it as follows:

Heretofore nitro-glycerine has been reduced to a gelatinous mass by dissolving gun-cotton or nitro-cellulose therein, and nitre has been incorporated in such mass. In the present invention neither gun-cotton nor other form of nitro-cellulose is required, but the cellulose is used in an unnitrated condition.

In order to carry the invention into effect, cotton or other form of cellulose is treated alternately with alkalies and acids, as in the cleaning of paper-stock, or in any ordinary or suitable way, in order to remove foreign materials and leave pure cellulose. This is then reduced to powder by a picker or grinding-cylinder, and is subjected in a close vessel to the action of high-pressure steam, until the reaction takes place by which the cellulose is converted into a gelatinous mass. At this moment the operation is stopped, the gelatinous mass obtained (which can be preserved indefinitely under water) is allowed to cool, and is then dissolved in or thoroughly and uniformly incorporated with nitro-glycerine, the result being a sort of jelly. The

solution or incorporation is effected by the aid of heat. A temperature of 40° centigrade is suitable, and can easily be obtained by a water-bath in which the water is heated to, say, 90° centigrade. Nitre is incorporated with the nitro-glycerine and gelatinized cotton described to form the new explosive—forcite.

The proportions may vary. One of the best compositions is nitro-glycerine, seventy-five; gelatinized cotton, seven; and nitre, eighteen. Dextrin can be used instead of a large part of the gelatinized cellulose. In such cases the following composition is preferred: nitro-glycerine, seventy; gelatinized cellulose, one; dextrin, five; nitre, fifteen; ordinary cellulose, nine. The ordinary cellulose is, or may be, in the form of powder.

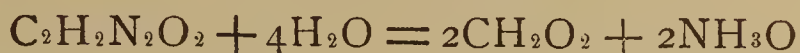
Forcite thus prepared is a plastic mass, having the power of nitro-glycerine, and being attended in its making, carrying and keeping, with less danger than explosive compounds before known, and even than “blasting” or “mining” powder, properly called. It has the remarkable and most advantageous property of exploding when confined or charged in a drill hole, as well as by the action of special primers or caps as by ordinary fuses, and of burning without explosion in the open air. Its manufacture is less costly than other compositions of nitro-glycerine. The nitro-glycerine is so perfectly united with the other materials that it is not separated by sulphuric ether or alcohol, and water has no action upon it. The nitro-glycerine therefore preserves its properties without alteration, even under water.

The *Jour. Chem. Soc.*, January, 1884, contains four interesting articles on the fulminates. The first (p. 13), by E. Divers and M. Kawakita, entitled “On the Constitution of the Fulminates,” discusses the work of Carstanjen and Ehrenberg* and of Steiner, and gives the results of their own investigation. They added dry fulminate of mercury† to fuming hydrochloric acid, without danger, and obtained the whole of the nitrogen as hydroxylamine chloride free from hydrocyanic acid. When dilute HCl was used much HCN was given off. By distillation with fuming HCl formic acid was obtained; careful

* *Proc. Nav. Inst.* 8, 667.

† This operation seemed to involve no danger. The fulminate was free from metallic mercury. The presence of the latter is due to the action being too much checked, in accordance with caution usually recommended. The action should be allowed free course.

search showed neither oxalic nor glyoxylic acid among the decomposition products. The authors then conclude that



represents the change which mercury fulminate suffers under the influence of concentrated hydrochloric acid.

On page 19, E. Divers treats of the "Theory of the Constitution of the Fulminates." The knowledge that the fulminates contain two isonitrosyl radicals or their equivalent, and two formic carbons, greatly simplifies the question as to the constitution of fulminic acid and divests the answer of much of its difficulty.

A theory of the constitution of the fulminates must, before it can be accepted, include an explanation of the formation of these bodies; of their capacity to yield cyanogen compounds, and to yield all their nitrogen as hydroxylamine, and all their carbon as formic acid; of their general if not entire disability to give dicarbon decomposition products; of the difficulty in replacing more than half their silver or mercury by another metal; of their reactions with chlorine and bromine, and of their explosive character.

A notice* of four of the formulæ which have been proposed will make apparent the extent to which they each fulfil these requirements of a theory of the subject:

Berzelius's modernized,	.	$\text{Ag}_2\text{O}(\text{AgN})_2\text{C}_4\text{N}_2\text{O}_3$
Kekulé's,	. . . .	$\text{NCCH}_2(\text{NO}_2)$
Armstrong's,	. . . .	$\text{HO.N:C:CH}(\text{NO})$
Steiner's,	. . . .	\text{HO.N:C:C:N.OH

The first furnishes an explanation of the explosive character of the fulminates, representing the metal as combined with both nitrogen and oxygen. It also shows a difference in the relations of the two atoms of hydrogen, or of the metal in place of them.

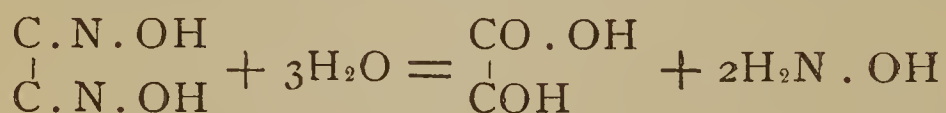
The second also explains, but in a less satisfactory way, the fulminating character of these salts. It shows why cyanogen derivatives are so readily formed from them, and represents half the nitrogen as oxidized and able to become hydrogenized and produce hydroxylamine just as nitroethane can. But it makes a nitroxyl radical to be introduced by nitrous acid, which, as Armstrong and Groves point out, it should not do. It entirely fails to account for the two kinds

* These Notes, 8, 667.

of acid properties the fulminates possess, and allows of only half the nitrogen becoming hydroxylamine.

The third formula explains the dual nature of the acidity, and also the formation of hydroxylamine and of cyanogen compounds. It is interesting as exhibiting the presence of isonitrosyl in fulminates before this had been established by experiment. But it has become open to the objection, through the recent conclusions of Victor Meyer and his school, that nitrosyl does not get introduced into a CH_3 or CH_2 -group, and probably its proposer would now reject it himself on that account.

The fourth formula is satisfactory as regards hydroxylamine and formic acid, but it does not make the cause of the explosive character apparent, nor the production of cyanogen compounds very probable, and, above all, it represents the two hydrogens as being of equal value. Besides this, it makes the hydrogen of isonitrosyl strongly basic, although this is not its character in other isonitrosyl compounds. We should expect, too, the formation of glyoxylic acid. Thus,



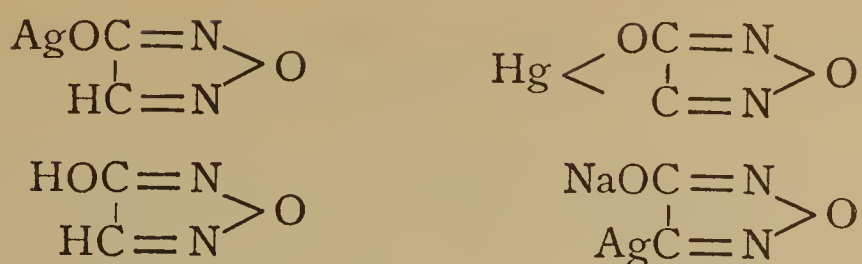
Divers, then, presents a theory of the constitution of the fulminates which he believes agrees with all the known facts. It is that they are formed from (1) an alcohol residue in which the hydrogen has been replaced by metal, and which retains only the carbon and oxygen; and (2) a condensed hydroxylamine residue.

Hydroxylamine is now always formulated as an amine $\text{H}_2\text{N.OH}$, but between doing this and formulating it as an ammonium hydroxide $\text{H}_3\text{N}(\text{OH})_2$ there is little to enable us to decide. Its want of odor is, perhaps, in favor of the latter view. But it may quite probably have still another composition. It may consist, like ether, of two molecules condensed into one with loss of a molecule of water, thus:

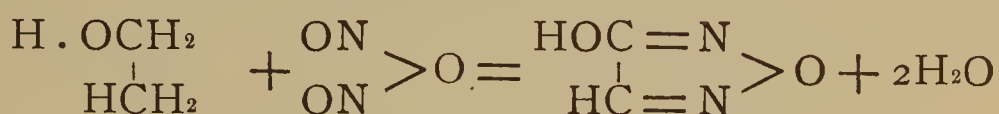


That is, there is no known reason why $(\text{H}_2\text{N})_2\text{O}$ should not be the composition of hydroxylamine, oxyammonia, or *amidogen oxide*, its derivatives being related sometimes to this condensed form, sometimes to its simple or alcoholic form of amidogen hydroxide. There is at least evidence of the existence of the condensed or oxide form, in the action of hydrochloric acid on hydroxylamine.

For these reasons Divers gives the following formulas for the fulminates:



and proceeds to consider their sufficiency for expressing the facts. First, as to formation. The alcohol yields two-thirds of its hydrogen to the oxygen of the nitrogen trioxide and its carbons unite with nitrogen.

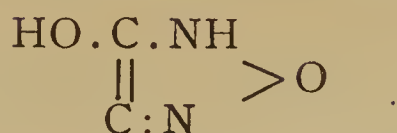


The fulminic acid here represented will either only be thus formed in the presence of mercury or silver nitrate, or it will be a transition body which would at once decompose but for the presence of the mercury or silver nitrate, with which it at once undergoes double decomposition, in virtue of being a cyanogen derivative, and just as the otherwise unstable hydrogen cyanide would do in similar circumstances. It is well known, on the authority of Liebig,* that nitrogen trioxide, passed into an alcoholic solution of either mercury or silver nitrate, precipitates fulminate without evolution of gas.

Secondly, as to the character of the metallic or basic element of their constitution. The formation of fulminates under the operation of mercury or silver nitrate, and the displacement of only half these metals from their fulminates by the action of soluble chlorides, are facts in entire agreement with what we know of the cyanides of these metals. Hydrocyanic acid decomposes strongly acid solutions of mercury and silver, and potassium cyanide is decomposed even by the oxides of these metals, as every chemist knows, and their cyanides give stability to the unstable alkali cyanides when combined with them.

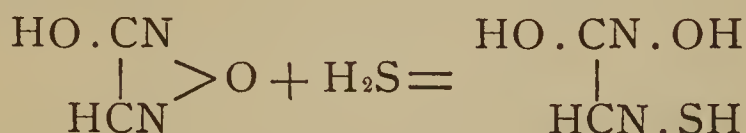
Thirdly, as to their explosive properties. To account for these, the presence together of the constitution of a cyanide and that of an oxygen salt seems fully sufficient. Berzelius' view of the matter resembles this explanation, allowance being made for the state of chemistry at the time he wrote. Indeed a formula may be given making out, as his does, that the metal is half united to nitrogen and half to oxygen.

* See page 108.

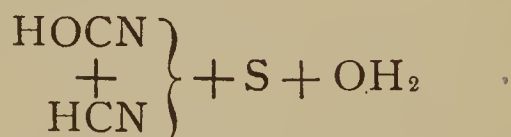


This formula is compatible with most of the facts; but that of the formation from alcohol is, as regards the transference required of the hydrogen from the carbon to the nitrogen, difficult to explain. Its relation to hydroxylamine is also not very simple.

Fourthly, as to the production of cyanogen compounds in their decompositions. This follows from the nitrogen being directly united to the carbon. The union with hydrogen sulphide (Steiner) may take place in this way,



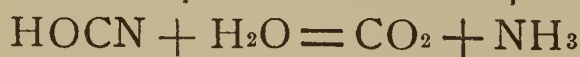
This becomes, in presence of water,



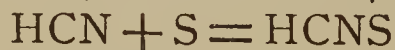
and then with a second molecule of hydrogen sulphide,



besides

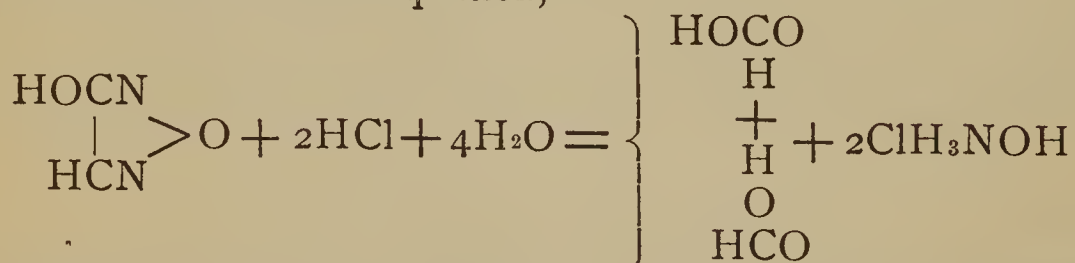


and



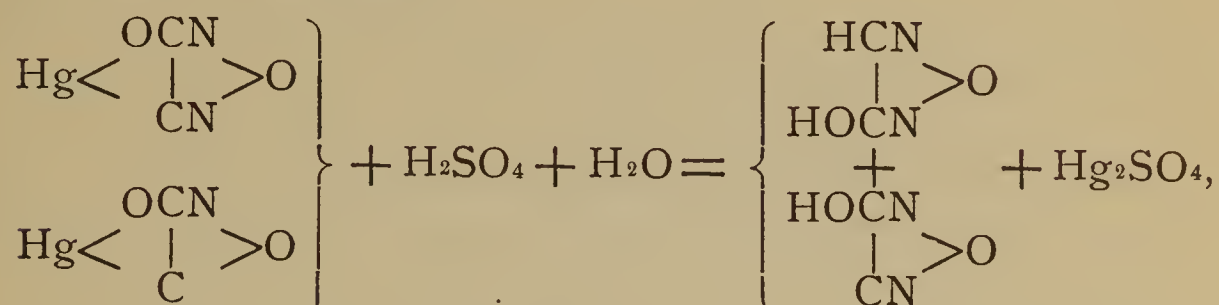
Gladstone's formation of urea by ammonia and hydrogen sulphide follows from the preceding representation, in which cyanic acid appears, as this would, of course, give urea with the ammonia also present.

Fifthly, as to the formation of hydroxylamine and formic acid. To explain this we have the equation,



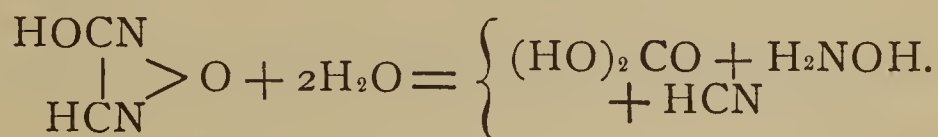
the $\equiv \text{N}_2\text{O}$ taking one molecule of water to become 2 ($=\text{NOH}$), and the C_2 taking another to separate them (as when oxalic acid becomes formic and carbonic acids, and just for the same reason that they are only loosely held together, through all the ethane-hydrogen having been displaced). Each $=\text{CN}-$ takes a molecule of water to separate its elements to form on the one side carbonyl and on the other amidogen, as is usual with the cyanogen radical.

The production of formic acid and other monocarbon compounds only is thus seen to be consistent with the dicarbon constitution derived from alcohol, while the formation of oxalic acid is not very improbable, provided there is a source of oxygen, but Divers and Kawakita were unable to obtain it. The reaction for carbonic acid is as follows in its first stage,

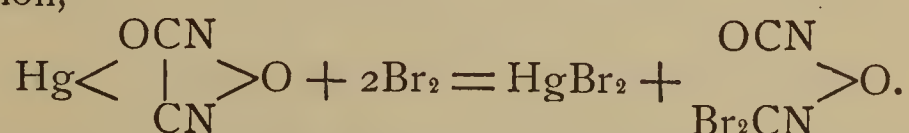


and then the fulminic acid shown in the upper line yields formic acid, and the lower (transition) acid yields formic acid and carbonic acid by further hydration.

Carbonic acid and hydrocyanic acid are also formed together under the influence of dilute hydrochloric acid. In this case only half the cyanogen of the fulminate undergoes hydration—the half combined with hydroxyl and apparently therefore less stable than the other:



Lastly, as to the action of bromine or chlorine. The primary reaction of bromine to form a body corresponding in composition with fulminic acid, but certainly not in constitution, admits now for the first time of ready explanation, without resorting to intra-molecular transposition,



The product cannot on the present view retain its generally accepted name of dibromacetonitril, its carbons being detached. Its conversion into bromopicrin and cyanogen bromide by excess of bromine in alkaline solution, is as intelligible as the formation of bromopicrin by hypobromite in other cases:

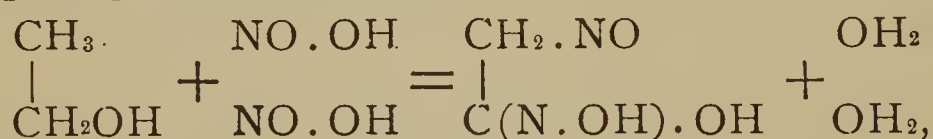


one atom of bromine replacing an atom of oxygen, and by thus leaving three-fourths of the combining power of the carbon to the nitrogen causing this to leave the other oxygen to the other nitrogen. Thus

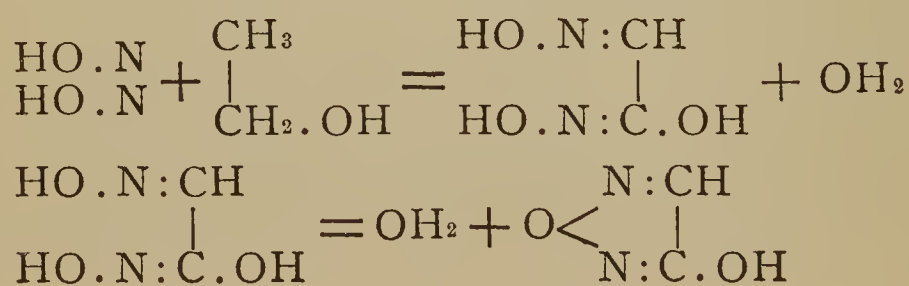
we get cyanogen bromide. Then the oxygen displaced by bromine acts in the form of hypobromite as an oxidizing agent on the NO, changing it to NO₂, the second atom of bromine combining with the carbon now only a quarter united to nitrogen.

In a "Note on the Formation and on the Constitution of the Fulminates," page 25, H. E. Armstrong states that the formula proposed by him was first publicly mentioned April 1, 1875, in the course of some remarks on Steiner's paper "On the Action of Ammonia and Sulphuretted Hydrogen on the Fulminates." His reasons for dissenting from Kekulé's formulas are stated in *Miller's Elements of Chemistry*, 3, 176, 5th edition. In proposing an alternative formula he was led to assume that half the nitrogen was present in the form of nitrosyl, NO, and the other half in the form of *hydroximide* N.OH, because he took it for granted that the fulminates were the products of the direct action of nitrous acid upon alcohol, it being known from Victor Meyer's researches that both of these groups could be introduced through the agency of nitrous acid; the assumption that the fulminates were nitroso-derivatives also appeared to account for the formation of nitro-trichlormethane on distilling them with bleaching powder, as it was known that certain nitroso-compounds were easily converted by oxidation into nitro-compounds.

But Victor Meyer's more recent researches have shown that the radical NO is not introducible into a CH₃ or CH₂ group by means of nitrous acid. The formula then requires modification, the equation expressing the primary reaction,

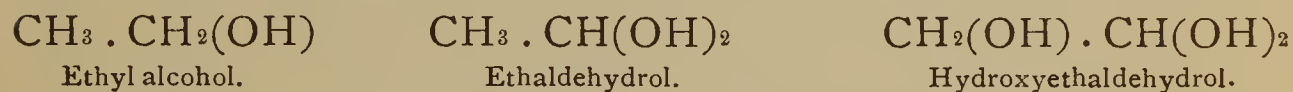


being thus far incompatible with our present knowledge as to the action of nitrous acid. Armstrong thinks Divers has made a similar mistake, since nitrous acid, and not its anhydride, must be the active agent, and therefore we may write his equation in the following manner without affecting the formula he deduces:

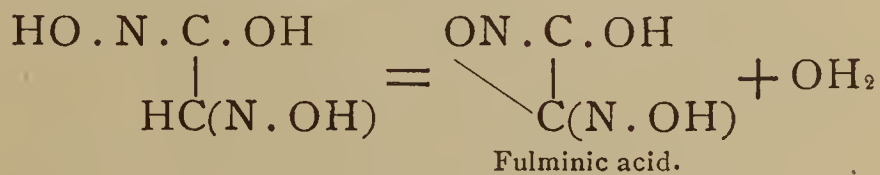
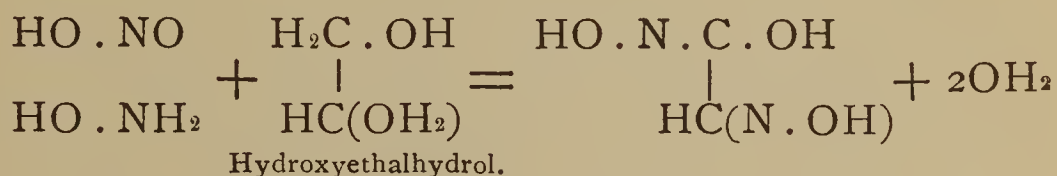


Here it is assumed that the CH_3 group exchanges 2H for N.OH ; a reaction which is as entirely without precedent as that involving the exchange of H in CH_3 or CH_2 for NO under the influence of nitrous acid; the conversion of nitromethane into "methyl-nitrolic acid" might indeed be cited, but can scarcely be regarded as a parallel case.

Whatever may be the force of this objection, Armstrong propounds a different formula on what he considers higher grounds, viz., from a consideration of what is probably the nature of the reaction between alcohol, nitric acid and mercury. In the first place, it is not probable that the fulminate is the immediate product of the action of nitrous acid, however produced, upon alcohol. It is well known that when treated with dilute nitric acid, alcohol undergoes hydroxylation, being finally converted into "ortho-oxalic acid" C(OH)_2 , C(OH)_3 , and Dr. Debus's classical research leaves little doubt that one by one the hydrogen-atoms are displaced by hydroxyl; in this way the alcohol is converted first into "ethaldehydol" (*Miller's Chemistry* 3, pp. 504, 715, 5th ed.), and then probably into "hydroxyethaldehydol,"



He is inclined to regard this last-mentioned compound as the primary source of the fulminate which is formed from it by the simultaneous—or it may be consecutive—action of nitrous acid and hydroxylamine,



That hydroxylamine may be formed by reduction of nitric or nitrous acid by ethaldehydol, or more highly hydroxylized derivatives of alcohol, is in the highest degree probable, especially after Dr. Divers' recent communication on the production of hydroxylamine in the dissolution of metals in nitric acid.

The formula now proposed differs but slightly from that previously brought forward, but it is a far better expression of our knowledge of

the fulminates. The representation of the carbon-atoms as exercising "triad" instead of "diad"* functions removes an obvious objection to his earlier formula.

According to Liebig (*Ann. Pharm.* 5, 287), fulminating silver separates in large needles and without the ebullition of the liquid, when nitrous acid is passed into an alcoholic solution of silver nitrate. Divers and Kawakita have repeated this operation and give their results on p. 27, under the title "On Liebig's Production of Fulminating Silver without the Use of Nitric Acid." There is an improbability of this reaction taking place, since it presents the first example of the displacement of the hydrogen of the $=CH_3$ group by isonitrosyl ($-NO-$), this having hitherto been effected only in the $=CH_2$ group; and, as another peculiarity, it presents an example of the formation of an isonitrosyl-compound by the action of nitrous anhydride in a neutral solution, instead of in a solution of nitrate at first alkaline and then made acid. It is not surprising, then, that they failed to verify Liebig's statement. They obtained the needle-shaped crystals, but found them to be silver nitrate mixed with a very small quantity of an organic silver salt. There was no fulminate. In fact their experiment in which silver nitrate, alcohol and nitric acid were used, while no nitrous acid was present, gave the best yield of fulminate. Armstrong, p. 27, says of this, that the fact that nothing but an energetic oxidation of the alcohol, by a mixture of nitric acid and either mercury or silver nitrate, seems effective, is entirely in accordance with the view of the constitution which he states above.

From the similarity of copper to mercury and silver in its relations toward nitric acid, as recently discussed by Divers in his paper on "Hydroxylamine," the authors were led to make several trials to prepare copper fulminate from alcohol, and either copper nitrate and nitrogen trioxide; or copper nitrate and nitric acid; or copper nitrate, nitric acid and nitrous acid, but all without success. The active catalytic oxidizing power of cupric salts, which affects the action of nitric acid upon copper (Acworth and Armstrong), and so readily causes the destruction of hydroxylamine (or isonitrosyl hydride), is sufficient to explain the failure. In proof of its being exerted in this case, they state that when nitrogen trioxide is passed for some time into an

* These expressions have reference to the definition of valency which, following Lossen, represents that a radical is monad, diad, triad, etc., according as it is in direct association with either one, two or three radicals.

alcoholic solution of copper nitrate, an abundant precipitation of copper oxalate is produced without any evident activity of the nitrous anhydride, which all along becomes quietly absorbed by the alcohol.

Lieutenant John P. Wisser has translated for *Van Nostrand's Magazine*, **31**, 113, August, 1884, an article by Lieutenant Max von Forster on "Experiments with Compressed Gun-Cotton." The first experiments to determine the efficiency of the explosive were made by placing the cartridges on lead cylinders 46 mm. in diameter (and of various heights) set upon small iron plates lying on solid ground. The wet gun-cotton (containing about 25 per cent. of water) was detonated by dry gun-cotton primers, containing 1 gram of mercuric fulminate, and these were fired partly by electricity and partly by a Bickford fuse. It was first remarked that the cartridges had a greater effect on the short cylinders than on the longer ones, and therefore only the results obtained with cylinders of the same length are compared together. (We may note here that it is not stated whether the cylinders were cast or drawn,* and that the system was not a rigid one.) On making this comparison for some nine experiments, where cartridges of various lengths were employed, the author concludes that in the case of dry gun-cotton no increased effect is produced by increasing the weight of the charge if at the same time the length of the charge is increased, for "it appears that in a long cartridge of dry gun-cotton the upper parts cannot transmit their detonation to the lower parts in the same explosive shock as that effected by the initial detonation of the primer, and hence it follows that in long charges of dry gun-cotton it is better to use several primers, placed some distance apart, and to fire them by electricity, in order to produce the greatest possible effect of the total charge."

When, however, gun-cotton containing 50 per cent. of barium nitrate was used it was found, in comparing cartridges of different lengths, that the effect increased with the weight in the longer ones, but not in a direct proportion, while with dry gun-cotton it diminished in this direction. With wet gun-cotton the effect was still greater than with the nitrated cotton, and it is held that in this substance the explosive wave is propagated with equal velocity throughout the entire length of the cartridge. The character of the impressions made on the cylinders also shows the more rapid action of the wet gun-cotton. Similar results were obtained with panclostite and

* Nav. Inst. Proc. **8**, 664, and **9**, 288.

Sprenkel's mixtures. The author claims that these experiments confirm the statements of Abel in *Dingler's Polytechnisches Jour.*, 1874, in regard to the relative rapidity of the propagation of the explosive reaction in wet and dry gun-cotton, and he also extends the comparison to the effects produced.

In the article cited Abel held that "the more energetic action produced when gun-cotton and its preparations are detonated in a moist condition, has furnished the striking proof that the detonation is transmitted the more easily, and the transformation of solid to gas and vapor takes place the more suddenly, the less the compressibility of a given explosive mass subjected to the action of a sufficient initial detonation. Since the water replaces the air contained in the compressed masses, the propagation of the detonation will evidently be favored by the increased resistance which the particles offer during the instant of detonation." Lieutenant von Forster takes exception to this on the remarkable ground that wet gun-cotton is more easily compressed and less compact than dry, a proof given being that when dry compressed gun-cotton is to be reworked it is first moistened in order to facilitate the crumbling. Having passed this criticism the author proceeds to restate as his own, but in other words, the theory of Abel given above.

A most curious and, we believe, entirely original, observation made in these experiments is the fact that when a piece of compressed gun-cotton is detonated on a plate of iron, an accurate impression of the form of the under surface of the gun-cotton is produced. Every angle, every projection and every indentation present in the gun-cotton is impressed on the underlying iron. The author gives an explanation which is as novel as the observation. He holds that the gases produced have copied the form of the gun-cotton and transferred or transmitted it to the iron, "that the gases acting on the iron have occupied exactly the same space, and no more, than the solid explosive previously occupied"; and hence he concludes "that only the gases evolved by the very undermost layer of gun-cotton act on the iron, while the others are lost."

Before meeting with this article of Lieutenant von Forster's we saw similar impressions produced in iron by the detonation of disks of gun-cotton upon the iron,* but we supposed that, as the detonator was placed in the top of the disks, the impression was produced by the lower part of the disks being driven into the iron, just as any other resisting body interposed in the path of the explosive wave

would have been. Of course we are met here by the difficulty that this hypothesis implies (1) that the pressure exerted upon the residual mass of gun-cotton is transmitted more rapidly than the explosive reaction is propagated within the mass, and (2) it also implies a great rigidity or coherency for this mass. The last condition is, however, a property of masses of matter when moving at great velocities, as is seen in the well-known candle experiment, and in the cutting of steel by soft iron and the like. The difficulties presented in the first condition do not seem so great as those in Lieutenant von Forster's hypothesis.

From his observations on the effects of the exploding of gun-cotton in drill holes Lieutenant von Forster concludes that its action is more sudden and local than that of dynamite, and he believes that the effect would be increased if we could give the gases of the detonated gun-cotton a fixed direction towards the object. In considering this problem he observes that the explosion takes place in a cartridge in the direction away from the detonating primer, and he finds a marked difference in the results of his experiments when the primer is placed on the end of the cartridge in contact with the target rather than on the end of the cartridge away from the target. He considers the simplest explanation of this fact to be, "that the detonating gases of the primer form, to a certain extent, a dam, so that they offer from the beginning a resistance to the gases generated from the gun-cotton, and thus press them toward the other side. Even a very weak dam of loose earth acts on the gases of the explosive, why not the energetic detonation of the mercuric fulminate?" He also says that "this fact may be explained by the transfer of the vibrations of the gases of the primer to those of the gun-cotton, when the gases of the primer have a fixed direction." Lieutenant von Forster states that the point in the cartridge at which the original direction of the gases is maintained has not yet been determined with certainty, but in his experiments the distance does not seem to be very great; yet in the case of a cartridge of a weight of over double the diameter (*sic*), 70:30, the direction given by the initial detonation becomes quite noticeable. We, too, have observed the difference in effect due to the difference in the position of the primer, but had believed that it could best be explained by Berthelot's theory of the propagation of explosive reactions.*

* Sur la Force des Matières explosives, I, 73: 1883.

In addition to placing the primer on the side of the cartridge away from the object, the author proposes the use of a cartridge which is hollowed out on the end opposite the primer. In examples given, where cartridges of the same cross-section were exploded on iron plates, the hollow cartridges, although of less weight, produced twice the depth of impression that the solid ones did.

In the second part of his memoir the author treats of his method of rendering gun-cotton impermeable to moisture. Compressed wet gun-cotton has many inherent disadvantages. The water evaporates readily and must be constantly renewed, though this difficulty may be greatly diminished by careful packing and storing; it crumbles easily, and even when well packed may suffer much in long-continued transportation; finally it is subject to the action of a fungus which will in time destroy its structure. The presence of paper in the packages promotes the formation of this fungus and should be carefully avoided. To reduce these disadvantages the author proposes to dip the cartridges in some solvent, such as acetic ether or nitrobenzene, for 15 to 20 seconds, then to take them out and allow the solvent to evaporate. A coating is thus formed on the surface which protects the cartridge from crumbling and prevents fungoid growth. Where an uncoated cartridge will dry in several days, a coated one will require several weeks. Dry gun-cotton cartridges may be treated in the same way, but the author prefers to coat only the cavity for the reception of the primer by this means, and to coat the remainder of the cartridge with melted paraffin. An ingenious application of this invention is in its use for submarine mines, which will remain explosive for a certain fixed time, and after that time will become of themselves inexplosive. This is effected by coating a cartridge so as to render it impermeable and then slicing the coating off from the bottom. When immersed in water the liquid will gradually soak in until the whole is wet and hence inexplosive. The time required is dependent on the length, area, density and composition of the cartridge. A cartridge of pure gun-cotton 100 mm. high and of a density of 1.1 remains explosive for about 8 hours, while in 11 hours it is completely saturated and inexplosive. A cartridge of gun-cotton mixed with saltpetre remains dry for a long time. A rubber tube may be used for protecting the priming.

In explosions under water it often happened to the author that, when the priming cartridge was adjusted by a copper lining, the gun-cotton charge began to burn or "to decompose into dense red fumes,

nitrous acid fumes, etc., but did not detonate. This decomposition of gun-cotton into nitrous acid fumes, etc., by an insufficiently energetic initial detonation of the primer, appears not to have been elsewhere noticed." It seems to us that this observation is not new, though we cannot recall the reference, but we do find it recorded* that when gun-cotton burns from contact with a heated metal the oxides of nitrogen appear among the products.

In treating of the spontaneous decomposition of gun-cotton, the author says that he is in possession of a piece of compressed gun-cotton made in 1878, which was not completely washed and in which some acid remained. The piece was preserved during this time in a chest kept in a dry place. It is now completely decomposed and has become a soft, greenish mass, which has lost the structure and appearance of gun-cotton, and when pressed, yields a glutinous liquid. It smells sour, burns, when ignited, with a white flame (gun-cotton with red flame), and emits no appreciable vapors. No pressure has been observed in the air-tight preserving-jar, in which a part of this experimental prism of gun-cotton has been preserved since the decomposition began. This experiment shows that the spontaneous decomposition of gun-cotton may take place without the production of flame, and the author believes that a spontaneous combustion of gun-cotton has never occurred. Of course, gun-cotton subjected to high temperatures such as can only be brought about artificially, temperatures above 120° C, is not included here. Good gun-cotton is pronounced sufficiently stable for all practical purposes.

How many unforeseen accidents may cause combustion is proven by the following experiment, communicated to the author by Prof. Kraut, of Hanover. If we take a good handful of simple cotton wadding, set a portion of it on fire, and wrap the other part around the kindled point so that the air is excluded, the piece of wadding may be wrapped in paper and preserved for months. If, at the end of this time, the wadding is unwrapped and air admitted, the part kindled months before goes on burning and consumes also the rest of the cotton. How often may this phenomenon have occurred when, in the case of the combustion of ordinary cotton, in large bulk, it was believed to be due to spontaneous combustion? With gun-cotton it is probably often the same.

* *Traité sur la Poudre*, E. Désortiaux, 2, 647, 1878, and *Die explosiven Stoffe*, Böckman, 248, 1880.

We must refer to the original paper for the many drawings illustrating the experimental results.

The current press reports that Edison has proposed the use of a detonating mixture of hydrogen and oxygen for war purposes. He fixed two platinum wires, separated by a short space, in a thick glass tube; filled the tube nearly full of water and then sealed it hermetically. The wires were then connected with a dynamo machine, the current made and the water decomposed by electrolysis, by which means an enormous pressure was developed, which was sufficient to produce an explosion. He claims that this explosive is portable, cheap and safe, since the glass and its contents are absolutely non-explosive until contact is made, and he proposes it for use in the place of powder, in guns, in blasting and for torpedoes. For the latter purpose the tube may be buried in the ground, and after connecting the wires with a small battery the current may be so regulated as to explode it in a day, a year, or even ten years.

Under the title "Über die Analyse der Sprengstoffe," Dr. W. Hampe has reprinted from the *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, 31, 1883, a summary of the various processes proposed and in use for the analysis of explosive substances, to which he adds a method of his own devising. It is impossible to repeat the descriptions here without reproducing some of the many figures of apparatus which the pamphlet contains, and we must content ourselves with calling the attention of those who have such analyses to make, to the work.

To the courtesy of Captain Philipp Hess, of the Austrian Engineers, we are indebted for a copy of his report of the German Health Exhibition of 1883, under the title "Hygiene und Rettungswesen mit Bezug auf die Explosivstoff-Industrie." The topics treated of are: 1. General description of explosive substances; 2. Methods for analyzing and testing the stability of explosives; 3. The construction and arrangement of factories and magazines for explosives; 4. The precautions taken against the dangers inherent to the explosive industry; 5. The literature of the subject. This paper forms an excellent supplement to Hampe's, mentioned above, as it gives methods for testing in the laboratory the condition of stability of these substances. It is very full, too, in its descriptions of safety lamps,

thermometric and electric alarms, fire extinguishers and the like, while it contains over sixty excellent illustrations of the apparatus and devices described. The pamphlet is a reprint from the *Mittheilungen ii. Gegenstände des Artil.- u. Genie-Wesens*, and is dated Vienna, 1884.

M. Pétry has devised the following process for manufacturing the explosive paper which he calls dynamogen.* In an enamelled pot containing 150 grams of pure water he dissolves 17 grams of yellow prussiate of potash, and, when it is heated to boiling, adds 17 grams of charcoal, stirring the mixture well together. Allowing the whole to cool somewhat, he adds, successively, 35 grams of potash, 70 grams of chlorate of potash, and 10 grams of starch, triturated in 50 grams of water. The whole is stirred so as to constitute a very thin paste, which is spread with a brush over ordinary filtering paper. The paper is dried upon a moderately heated plate, and the other side is varnished in like manner. After three coats have been laid upon each side the paper is dried. It can be cut without danger and made into cartridges.—*Chron. Indust.*, Jan. 1, 1883; *Jour. Frank. Inst.*, [3] 86, 468, Dec. 83.

This recalls the “Explosive Paper” described as follows in *Boston Journal Chemistry*, 9, 112, Apr., 1875. Make a mixture of saltpetre 8 parts; chlorate of potash, 5 parts; charcoal powder or pulverized coal, 1 part; fine sawdust of hard wood, 1 part; and a little mucilage, gum or other binding material; put water enough on it to change it into a pasty mass, work it well through, and soak strips of heavy blotting paper in it. If you dry these strips you obtain explosive paper; if you roll them up tightly when wet and let them dry, you obtain little blocks which, when confined and fired, will explode with great violence, but will not easily go off by percussion or friction alone.

Mr. C. John Hexamer continues† his discussion of the means for the “Prevention of Dust Explosions and Fires in Malt Mills” in the *Jour. Frank. Inst.*, 116, 200, Sept., 1883, and describes several devices which he has invented for this purpose.

The *Bulletin of the Edison Electric Light Company*, No. 22, April 9, 1884, announces the installation of a 100-light machine in the government powder mill at Spandau, Prussia.

*Proc. Nav. Inst. 8, 449.

*Proc. Nav. Inst. 9, 295.

At a factory in Neusalz a large cast-iron wash-kettle was used to hold water, into which melted iron was allowed to flow, in a moderate stream, for making iron shot. On October 23, 1882, one of the workmen, by mistake, allowed the iron to flow too rapidly. There was a sudden development of steam, which threw out a part of the water, frightening the laborer and causing him to drop his ladle, so that about 20 kilogrammes (44 pounds) of melted iron fell at once into the water. There was an immediate rapid outburst of steam and a loud explosion, which shattered the kettle into fragments, tore up the wood-work, threw the workman nearly eight feet backwards and broke his right leg. Only a very small piece of the kettle was found where it stood; some of the pieces were thrown to a distance of about fifty feet.—*Jour. Frank. Inst.*, **116**, 237, Sept. 1883; *Dingler's Poly. Jour.*, March 7, 1883.

Table showing the percentage of Nitro-glycerine contained in the different grades of Atlas Powder, and the distinguishing marks of corresponding grade of "Hercules," "Giant," "Etna," "Hecla," and "Judson" Powders.*

Atlas. (Standard.)		Hercules.		Giant.		Ætna.		Hecla.		Judson.	
Brand.	Per Cent. N. G.	Brand.	Per Cent. N. G.	Brand.	Per Cent. N. G.	Brand.	Per Cent. N. G.	Brand.	Per Cent. N. G.	Brand.	Per Cent. N. G.
.....	...	.....	...	.....	...	.....	...	.....	...	R.R.P.	5 and under.
.....	...	.....	...	.....	...	.....	...	.....	...	F.	10
F+	15	.....	...	.....	...	No. 5.	15	.....	...	FF.	15
E.	20	No. 4.	20	M.	20	.....	...	No. 3.	20	F.F.F.	20
E+	25	No. 4 S.	25	.....	...	No. 4 X.	25	No. 3 X.	25	.....	...
.....	...	.....	...	XXX.	27	.....	...	.....	...	.....	...
D.	30	No. 3.	30	.....	...	.....	...	No. 2.	30	.....	...
.....	...	.....	...	No. 2 C.	33	.....	...	.....	...	.....	...
D+	35	No. 3 S.	35	.....	...	No. 3 X.	35	No. 2 X.	35	.....	...
C.	40	No. 2.	40	No. 2.	40	No. 2.	40	No. 1.	40	.....	...
C+	45	No. 2 S.	45	No. 2 Extra.	45	.....	...	.....	...	.....	...
B.	50	No. 2 SS.	50	New No. 1.	50	No. 2 XX.	50	No. 1 X.	50	.....	...
B+	60	No. 2 SSS.	55	.....	...	.....	...	.....	...	.....	...
.....	...	No. 1.	65	.....	...	No. 1.	65	.....	...	.....	...
A.	75	No. 1 XX.	75	No. 1.	75	.....	...	No. 1 XX.	75	.....	...

* "Atlas Powder," a Nitro-glycerine Compound, p. 25, published by Repauno Chemical Co., Philadelphia, Pa.

NAVAL INSTITUTE, ANNAPOLIS, MD.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY PROF. CHAS. E. MUNROE, U. S. N. A.

No. VIII.

In the first number of these Notes attention was called to the growing importance to the student of explosives of the new study of thermo-chemistry, and frequent references have since then added force to this suggestion ; but the elaborate work of M. Berthelot, now before us, bearing the title of “*Sur la Force des Matières Explosives d’après la Thermochimie*,” shows most strongly the necessity of conducting our inquiries into the constitution and mode of action of explosive substances from this standpoint, if we wish to arrive at any rational conclusions and to discover the general underlying principles. This work is in two large octavo volumes, of over 400 pages each, and bears the imprint of Gauthier-Villars, Paris, 1883, which is a guarantee of excellent typographical form and workmanship. The work is announced as a “third edition, revised and considerably augmented,” but one would be at a loss to recognize the thin little duodecimo entitled “*Sur la Force de la Poudre*, 1872,” as the second edition of this work.

Although in civil life, yet Berthelot has had unparalleled opportunities for the study of explosive substances ; for, in addition to having served as president of the Scientific Committee for the defence of Paris in 1870, and having been delegated to fill the place formerly occupied by Gay Lussac upon the Advisory Committee on Powders and Saltpetre, he is President of the Committee on Explosive Substances, created June 14, 1878, where he has associated with him

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars.

some sixteen specialists from the Army, Navy, and the corps of Mining Engineers and Engineers of Powders and Saltpetre (among whom we note Sarrau, Sebert, Cornu, Vieille, Desortiaux and others), and in this position he has the assistance of a considerable laboratory force and all the resources of a highly centralized government at his command. It is then not surprising that, by April 5, 1883, his committee had completed twenty distinct researches, and had twenty-three others in course of execution.

The work now under consideration is based principally upon these researches, together with those of Berthelot and others in pure chemistry. The first part deals with the general properties of explosive substances, their chemical composition, the heat disengaged in their explosion, and the pressure of the gases produced; the duration of the explosive reaction; explosions by influence, and the explosive wave. The second part treats especially of the thermochemistry of explosive compounds, a chapter being devoted to the much-vexed question of the origin of the nitrates; and the third part considers the force of the explosive bodies. The work is replete with descriptions of the apparatus used, the methods pursued and the data obtained in these researches; but, as we have already noticed, in these Notes, many of the results as they have appeared in the professional journals, we will simply present the following tabular summary:

Nature of the explosive substance.	Formula.	Molecular weights in grams.	Heat disengaged at constant volume by one kilogram in calories.	Volume of permanent gas (1) per kilo-gram, in litres.	Specific pressure from experiments (3) (1 gram in 1 cm. ³) in atmospheres.	Velocity of the explosive wave per second, in meters.
Oxygen and hydrogen.	H ₂ + O	18	{ 3833 liquid water 3278 steam (1) }	1240	11960	2810
Chlorine and hydrogen.....	H + Cl	36.5	603	610	4940	"
Carbon monoxide and oxygen.....	CO + O	46	1483	480	4510	1089
Ethane and oxygen.....	CH ₄ + O ₄	80	{ 2669 liquid water 2419 steam (1) }	840	11420	2287
Ethine and oxygen.....	C ₂ H ₂ + O ₅	106	{ 3001 liquid water 2907 steam (1) }	630	8630	2482
Ethene and oxygen.....	C ₂ H ₄ + O ₆	124	{ 2753 liquid water 2592 steam (1) }	720	9940	2209
Cyanogen and oxygen.....	C ₂ N ₂ + O ₄	116	2263	580	8760	2195
Nitrogen sulphide.....	NS	46	694	485	8270	"
Nitroglycerine.....	C ₃ H ₅ O ₃ (NO ₂) ₃	227	{ 1579 liquid water 1480 steam (1) }	713	10950	5000 in 75% dynamite.
Nitromannite.....	C ₆ H ₈ O ₆ (NO ₂) ₆	452	{ 1526 liquid water 1459 steam (1) }	692	11500	"
Gun cotton.....	C ₂₄ H ₂₉ O ₈ O ₁₁ (NO ₂) ₁₁	1143	{ 1074 liquid water 1022 steam (1) }	859	10000	5000 to 6000
Potassium picrate.....	K C ₆ H ₂ (NO ₂) ₃ O	267	781	549	$\frac{5600}{n-0.14}$	"
Mercury fulminate.....	C ₂ H ₂ N ₂ O ₂	284	{ 463 gaseous mercury (2) 349 }	314	{ 6200 27400 (4) }	"
Diazobenzol nitrate.....	C ₆ H ₅ N ₂ (NO ₃)	167	688	818	about 7600	"
Gunpowder	{ 74.7 nitre 10.1 sulphur 14.2 carbon 1.0 water }		720 to 738	278 to 263	$\frac{2193}{n-0.68}$	"

(1) This volume represents the reduced volume. In those cases where the reaction produces aqueous vapor, the volume of this substance is included in the reduced volume, whereas in fact it is only gaseous at some temperature t higher than 0° ; that is to say, the volume assigned to the aqueous vapor ought to be multiplied by $1 + \frac{t}{273}$, t being the temperature produced at the moment of the explosion. But then the heat disengaged ought to be diminished by the amount absorbed in vaporizing the water, a quantity which Berthelot takes, for simplicity, as equal to 10000 cal. for 18 grams of water. He neglects on the other hand the effect of dissociation, since the value to be assigned thereto has not yet been determined. (2) The mercury is supposed gaseous, as it is considered at a temperature above 360° . The real volume is then $314 \left(1 + \frac{t}{273}\right)$. The heat disengaged has been diminished by the latent heat of vaporization of mercury. (3) These pressures represent the limit toward which the observed pressures tend under a *density of loading* of $\frac{1}{n}$ (1 gram of matter in n cm.³) when n tends towards unity. In the case where a non-volatile residue is produced, the volume of this residue ought to be deducted from n , as is done in the cases of potassium picrate and gunpowder. (4) In its own proper volume, that is to say, for a density of loading when $\frac{1}{n} = 4.43$.

In citing these results of Berthelot's work, it may be proper to call attention to a recent review by Prof. Remsen, *Am. Chem. Jour.* 6, 423, Feb. 1885, of "A Treatise on the Principles of Chemistry," by M. M. Pattison Muir. He says: "Chapter IV is devoted to the *Applications of physical methods to questions of chemical statics*. Of the physical methods the first considered are the thermal methods. The subject is treated clearly; indeed, it would be difficult to find anywhere a more satisfactory statement in regard to the method and results of thermo-chemistry than we here have included within fifty-odd pages. After showing that the thermal value of even the simplest chemical change is really the sum of various changes, some of which have a positive and others a negative value, and that in most, if not in all cases, it is impossible to assign values to each of the simple changes involved, the conclusion is drawn, that until 'the distinction' implied in the terms atom and molecule 'is practically recognized in thermal chemistry, we cannot expect any great advances to be made in applying the mass of data already accumulated to questions of chemical actions and reactions.'

'Berthelot's work is saturated with the conceptions of the molecular theory; but, by some fatal perverseness, he refuses to apply this theory to chemical phenomena. While recognizing the existence of molecules, and building his generalizations on a molecular foundation, he refuses to accept the conception of atom, or rather he hopelessly confuses it with that of equivalent. The molecule is for him a definite and definable portion of matter, the parts of the molecules are only numbers.'

"This criticism may sound harsh, but it appears to be just. At all events we shall be glad to hear what the disciples of Berthelot may have to say in reply. We commend this part of the book to the careful attention of those who have blindly 'pinned their faith' to investigations in the field of thermo-chemistry. While something has been learned, and much more will be learned, in regard to the nature of chemical action by a study of thermal phenomena, it must be acknowledged that the results thus far reached are extremely meagre." In this connection consult the same Journal 5, 147 and 293, also 6, 202.

Through the courtesy of Manuel Eissler we have received a copy of his "Modern High Explosives," in the form of a large octavo of 495 pages, published by John Wiley & Sons, 1884. The

book is arranged in three parts; the first of which describes the processes employed in the manufacture of high explosives, and the methods of analysis and chemical properties of these bodies and their constituents; the second treats of the methods for operating with these explosives; while the third deals with the principles of blasting, and gives the results obtained in many engineering, mining and military operations. Mr. Eissler designed, erected and managed the American Forcite Company's works,* and has had considerable experience in the use of high explosives, and hence he has been able to gather together and present in the last two parts of his book a large amount of information and data which will be of value and use to the practical man in determining the amount of an explosive necessary to do a given work and the best way of applying it. The first part, on the other hand, is quite unsatisfactory, as it is so marred by errors in chemical terminology and technical phrases as to be quite bewildering.

One of the most novel and interesting chapters in the book is the one on "Big Blasts," where, among other instances, it is stated that it sometimes happens in the system of hydraulic mining in vogue in California, that banks of gravel are met with which are so firmly cemented together as not to yield readily to the action of the water, while other banks are so high that it becomes dangerous to bring the stream sufficiently close for the water to exert its disintegrating force. Under these circumstances recourse is had to what is termed "bank-blasting," in order to loosen the earth so that it will break down under the pressure of the water, and enormous quantities of explosives are used for this purpose. Mr. Eissler gives a detailed description of the method of laying these charges, and he says that in the diggings at Smartsville, San Juan, More's Flat, Bloomfield, and elsewhere in California, it is an almost daily occurrence to fire blasts where twenty, thirty, and even fifty thousand pounds of explosives are used in a single charge, and that this system of large blasts is even become common in hard rock excavations, such as quarries and railroad cuttings.

We learn that a second volume is in course of preparation, and from the scope of the projected work it promises to be of great value.

A circular from the Judson Powder Company gives the following instances of "big blasts," in which this powder has been used:

* Proc. Nav. Inst. 11, 98.

June 29th, 1882, 23,000 pounds were fired in a limestone quarry at Glendon, Pa., and it is estimated that it moved 150,000 tons of rock. January 11, 1883, 29,000 pounds of frozen powder were fired at the same place with good results. At Shell Rock, on the Oregon R. and N. Co. R. R., 10,000 pounds of powder, in one charge, moved 56,000 yards of solid rock. At Jacob's Ladder, on the same road, 21,000 pounds of powder moved 110,000 yards of solid rock.

Through the kindness of Gen. Abbot we are in receipt of Addendum II of his Report on Submarine Mines,* in which the results of recent experiment on Atlas powder, Judson powder, Rackarock, Forcite, and explosive or blasting gelatine, are given.

Two grades of Atlas† powder, A and B, were used, of which the composition was :

Grade A.—Sodium nitrate,	.	.	.	.	2
Wood fibre,	.	.	.	.	21
Magnesium carbonate,	.	.	.	.	2
Nitroglycerine,	.	.	.	.	75
					<hr/>
					100
Grade B.—Sodium nitrate,	.	.	.	.	34
Wood fibre,	.	.	.	.	14
Magnesium carbonate,	.	.	.	.	2
Nitroglycerine,	.	.	.	.	50
					<hr/>
					100

The firing trial showed Atlas A to be precisely equivalent to dynamite No. 1, when fired under water ; while Atlas B, under the same conditions, showed an intensity of action in the horizontal plane equal to 99 per cent. of dynamite No. 1, for equal weights.

Several grades of Judson powder‡ were tested. The one most commonly used, and which is sold at the price of common saltpeter blasting powder, is the R. R. P., which has the composition :

Sodium nitrate,	.	.	.	.	.	64
Sulphur,	.	.	.	.	.	16
Cannel coal,	.	.	.	.	.	15
Nitroglycerine,	.	.	.	.	.	5
						<hr/>
						100

* Proc. Nav. Inst. 9, 287, 754.

† Proc. Nav. Inst. 11, 116.

‡ Proc. Nav. Inst. 11, 116.

It is manufactured at the New Jersey works by first grinding the niter, sulphur and coal separately, to a fine powder, and then thoroughly incorporating them in a barrel mixer to form a coarse mealed powder. This is then heated on a steam pan (150 pounds pressure and 350° F.), and constantly stirred until the sulphur melts and coats the particles of the niter and coal. The mass is then thrown out and allowed to cool, and it forms conglomerate grains, which are sorted by sieves and coated with nitroglycerine by stirring. The theory of this manufacture is the same as that claimed by Mr. Mowbray for his mica powder, viz: the coating of a non-absorbent base with nitroglycerine, by which the quickness of explosion is promoted. The prime difference between the powders lies in the fact that Judson employs an explosive base, while Mowbray's is inert. The advantage sought for here is to obtain the maximum potential energy of the explosive base through the initial action of the small charge of nitroglycerine.* The intensity of action of the R. R. P. of different makes, fired under water, was found to equal 38 to 39 per cent. of dynamite No. 1, while some of the other grades rose as high as 78 per cent. The lower grade seemed to be insensitive to the shock of the ball from a Springfield rifle at twenty paces, and when ignited by a match, in charges of 1½ pounds, it burned for about forty-five seconds with a strong yellow flame, but with no such flashing as occurs with ordinary gunpowder.

In addition to the rackarock mentioned in these Notes,† Mr. Divine, the inventor, has patented several other formulas in which the potassium chlorate is finely powdered and mixed with nitro-benzol and sulphur, or with "dead oil" of tar and sulphur, or with "dead oil" of tar, sulphur and carbon disulphide in varying proportions. Several of these mixtures were tested and they gave results varying from 77 to 104 per cent. as compared with dynamite. Gen. Abbot seems to be favorably impressed with this explosive and recommends its trial in blasting and for use in shells.

The forcite gave results which varied, with the grade, between 88 and 133 per cent., and hence it compared favorably with Nobel's explosive gelatine. It was found that the higher grade was the more liable to sympathetic explosions, but that both those tested were much less sensitive than dynamite No. 1 under similar conditions. When the forcite-gelatine was exposed for several hours to a

* Proc. Nav. Inst. 8, 665.

† Proc. Nav. Inst. 9, 755.

temperature of 100° F., a slight exudation of nitroglycerine was observed. The manufacturers state that the base for all grades of forcite* is mixed with a special kind of "cellulose" whose formula is $C_6H_7O_2 \left\{ \begin{array}{l} NO_2 \\ C_2H_3O_2 \end{array} \right.$, which permits them to operate and manufacture cold. As they state that in manufacturing Nobel's gelatine a temperature of 170° F. is necessary for incorporation, and that this temperature renders the nitroglycerine very sensitive to concussion and quite dangerous to transport, they claim the cold process as an advantage. A hydrocarbon is used as a solvent for the forcite mixture, and its action renders the product water-proof.

The blasting gelatine used in these experiments came from Nobel's Explosive Co. of Glasgow, Scotland. It was without camphor, but directions for easily camphorating it are given. The composition was 92 per cent. nitroglycerine and 8 per cent. nitro-cotton. The test gave the relative intensity as 142, showing this to be the most powerful explosive yet tested at the station. Its sensitiveness to sympathetic explosion was the same as that of the higher grade of forcite.

Gen. Abbot gives a tabular view and also a graphical diagram of relative intensity of the modern high explosives, as shown by the results obtained in his experiments, and he draws the following conclusions :

I. The assumption sometimes made that the economic value of a dynamite is simply proportional to the known percentage of nitroglycerine it contains is shown to be erroneous. A judiciously selected base adds enormously to the energy developed by the nitroglycerine alone.

II. There appears to be an advantage in gelatinizing the nitroglycerine before its absorption.

III. The composition of the base is practically as well as theoretically a very important matter. For example, the lower grades of forcite and rendrock, which are very similar in composition, show nearly equal intensity; and the same is true of dynamite No. 2 and Vulcan No. 2; but both grades of electric powder fall far behind these rivals.

IV. It seems to be a general law that with any particular kind of base there is an economic gain in increasing the percentage of nitroglycerine up to a certain point, but that beyond that point the advantage ceases.

* Proc. Nav. Inst. **11**, 99.

The instructors in the Department of Ordnance and Gunnery, U. S. Naval Academy, have prepared a work for use in instruction in that department entitled "Textbook of Ordnance and Gunnery," 1884, in which the most modern advancements in the construction and use of ordnance and ammunition are described by the aid of many excellent plates and cuts, while the latest data are discussed according to the most approved methods. The progress in the art of gunnery is so rapid that the best textbooks and treatises soon become imperfect, and it is for the purpose of bringing the instruction into accordance with modern views and methods that this book has been prepared.

A new powder known as the Cocoa powder, and made by the Rottweil-Hamburg Powder Co. at their works at Düneberg, near Hamburg, has been exciting some attention abroad. It is formed into hexagonal prisms, with one canal, and is of the color of cocoa, whence the name. Two pamphlets issued by the firm, dated 1882 and 1883, and entitled "Trials executed with Prismatic Powder," have come to hand, from which we extract the following:

Powder in prisms of 50 mm. was tested in a 21 centimeter gun of 30 calibers length against ordinary prismatic powder. The Cocoa powder is designated as C/82, the ordinary prismatic as C/75. The results are given in the following table:

Powder.		Weight of Projectile Kg.	Muzzle Velocity. M. S.	Pressure of Gas in Atmospheres.		Energy of Projectile.		
Description.	Charge. Kg.			Rodman Gauge.	Crusher Gauge.	Total.	Per Kg. of Powder.	Per Atmosph'e Rodman Gauge.
C/82	39	140	481	1935	1975	1648	42.3	0.85
C/75	39	"	490	2680	2825	1713	43.9	0.64
C/82	42	"	499	2130	2150	1776	42.3	0.83
C/75	40	"	497	2830	2905	1761	44	0.62
C/82	45	"	519	2365	2380	1922	42.7	0.81
C/75	40	"	506	3035	2970	1827	45.7	0.60
C/82	48	96.5	606	2320	2255	1810	37.7	0.80
C/75	42	"	607	3035	3015	1814	43.2	0.60

The above figures show:

1. That the new Düneberg powder, C/82, produces about 700 atmospheres less pressure than the prismatic powder C/75, while the velocity remains the same.
2. That the powder C/82 produces 33 per cent. more energy per atmosphere pressure than C/75.

3. That with the powder C/75, a 21 cm. shell of $3\frac{1}{2}$ calibers length, weighing 140 kg. attains a velocity of 500 metres, only at a comparatively high pressure of gas, whereas the new powder produces velocity at a proportionately low one.

While a charge of 40 kilos of the old pattern may be deemed too great, on account of the high pressure of gas it produces, a charge of the powder C/82 may safely be increased to 48 kilos; the pressure thereby produced, reached according to the Rodman gauge but 2615 atmospheres, according to the crusher gauge but 2570 atmospheres, the muzzle-velocity was 537 metres.

Other properties claimed for the new powder are comparatively little smoke and a slow rate of burning when unconfined. It was especially noticed at the trial that C/82 gave less and thinner smoke than C/75, which is of the greatest importance, as great quantities of dense smoke dispersing slowly may stop the firing, as was recently the case during the bombardment of Alexandria.

A grain of C/82 powder when ignited in air did not explode like C/75 and C/68 powder, but burned slowly, showing a red flame. A closed box containing 55 kg. of C/82 powder was ignited. The powder burned out in about 10 seconds without any detonation (?) whatever. It was found that the screwed lid had been loosened, without however being thrown off the box, and that with the exception of a few slight burnings the lid presented the same appearance as before the experiment. The box also escaped without any damage. This property of burning without explosion is of value in the use of powder. Another feature in the powder is that it attracts moisture less than powder of the old pattern. Experiments made with the 40 centimeter gun of 25 caliber length gave as good results as those above quoted. These experiments were made in 1882.

The pamphlet for 1883 contains data from tests with guns of various sizes. Among them we observe, that in the 28 cm. gun of 35 calibers length, with a projectile weighing 345 kg., 100 kg. of C/82 powder gave a muzzle velocity of 525 metres and a pressure by the Rodman gauge of 2325 atmospheres, and by the crusher gauge 2350 atmospheres. Both pamphlets contain tabulated results of many trials.

It has been tried in Russia in small arms, and in France in large grains, and is reported to have given good results. A resumé of some of the firing trials will be found in the *Revue d'Artill.* 21, 77 and 475, 1885.

In the *Jour. Roy. United Service Inst.* 28, 379, 1884, under the subject of "Gunpowder considered as the Spirit of Artillery," Col. Brackenbury, R. A., says that two firms in Germany are making the above mentioned powder, one calling it Cocoa and the other Brown Powder. The proportion of sulphur in its composition is small, and the charcoal, if we may so call it, is different from that generally made. When first brought forward it was irregular in its action, but later samples have given very good results, about the same as Waltham Abbey C₂, and with a less amount of powder. They are prepared to make it at Waltham Abbey if its value is established, but some claimed that its erosive action is too great.

Considerable space is devoted to the subject of blending powders, and cuts are given illustrating the method followed. In this connection he says an idea has lately been set afloat that this process can be got rid of and powder made so regular that it will need no blending, but up to the present time there appears no prospect of any such consummation. Gunpowder is such a nervous and sensitive spirit, that in almost every process of manufacture it changes under our hands as the weather changes. Sometimes its sensibility can be detected and allowed for, as in the process of pressing it into moulds, when we can by actual trial tell what densities we are getting, and give more or less pressure as is required. For instance, on the morning of the 13th June, 1882, the pressure had to be applied for 45 seconds to obtain the required density. Later in the day only 29 seconds were required to obtain the same density, so that in the morning of a June day half as much again time was required as in the afternoon. On the 30th June, 1882, during part of the day the time was as short as 26 seconds; on the 11th December the time varied between 98 and 84 seconds to get the same density as was obtained in June. In the other stages of manufacture we have no such indications as in the pressing process, but it is a fact that not only the warmth of summer and the cold of winter affect it greatly, but the morning mists, the sunshine of midday, the dews of evening, yea, even a passing cloud, tell upon its nervous temperament. As a mitigation of the weather difficulty, they are to try warming a set of houses with warm water.

Under the title "A Flashing Test for Gunpowder," Chas. E. Munroe discusses in the *Jour. Am. Chem. Soc'y*, 6, 7, 1884, the merits and defects of the method in use as described in the "Ordnance Instruc-

tions U. S. Navy," p. 345, and Smith's "Handbook of the Manufacture and Proof of Gunpowder," p. 83, and the suggested improvement of Marvin in his "Objects and Resources of the Naval Experimental Battery," p. 18, and also the pyrographic method invented by Colonel Chabrier, and described in the *Comptes Rendus*, 78, 1138, 1874, and the *Revue d'Artillerie*, 4, 396, 1874. He then describes his own process, which consists in flashing the powder on a sheet of dampened paper which has been coated with Turnbull's blue—in fact, such blue paper as is produced in the "Blue Print Process" of photography. The result will be that if the paper is washed, after a half minute exposure to the action of the powder residue, it will be found covered with yellowish or white spots, that have been caused by the action of the alkaline salts which result from the combustion, and which have the power to discharge the blue color; and the author holds that the fineness of the spots and the uniformity of their arrangement about the explosive center are determined by the thoroughness of the incorporation of the powder.

The advantage which is claimed for this new method is, that as the test papers, when dried, remain unchanged for years, they may be filed at the factory with other data concerning a given powder, or that, in the case of the government, they could be inclosed with the quarterly returns of the inspecting officers at distant stations, to be examined by some expert in the Bureau. Specimens of the tests of standard powders could also be furnished inspecting officers, to guide them in the interpretation of the results of their tests, and finally, a sample of the required test might be attached to the specifications for a gunpowder to be purchased. A detailed account of the method can also be found in the Text-book of Ordnance and Gunnery, U. S. N. A., p. 93, 1884, and Van Nostrand's Eng. Mag. 32, 427, May '85.

We are in receipt from Luckhardt & Alten, Cassel, Germany, of a thin pamphlet, entitled "A Few Words on the Present State of the Manufacture of Gunpowder," in which it is claimed that the German gunpowders are now superior to those of all other countries, and are largely purchased by foreign governments, and that the superiority is due solely to the severity of the tests applied to the materials and the manufactured product, and to the delicacy and accuracy of the instruments employed in making these tests. The pamphlet then describes, with illustrations, a considerable assortment of apparatus

which this firm supplies, and among them, besides the densimeters, chronographs, pressure gauges, and the like, we especially note an apparatus for measuring the length of cylinders in crusher gauges, which it is claimed will measure a difference of $\frac{1}{40}$ of a millimeter ($\frac{1}{1000}$ of an inch), another for measuring the length of cut in the Rodman method, which will read to the $\frac{1}{100}$ millimeter ($\frac{1}{2500}$ inch), and another still for measuring the thickness of wire and width of mesh in metallic powder sieves, which also reads to the $\frac{1}{100}$ millimeter.

The newspapers for some time past have contained notices of the dynamite gun now on trial at Fort Hamilton. One of the fullest descriptions, with an illustration, is to be found in the *Scientific American* 50, 214, April 5, 1884. This represents the 4-inch gun building at the Delamater Iron Works, N. Y. It consists of a brass tube, 40 feet in length and $\frac{1}{4}$ inch thick, mounted on a high steel girder. The latter is trunnioned and is pivoted on a cast-iron base, thus enabling it to be swung into any desired position and range. To assist in the latter operation guys are placed on either side of the base, and their length can be altered and fixed by means of hand-wheels.

Compressed air is introduced to the gun from below and passes up through the center of the base, the pipe connecting with one of the trunnions (which are hollow); it is then carried into a pipe at the side of the gun which leads into the valve. This valve is a continuation of the breech of the gun, with which it is connected by a short passage.

An important feature of the system, and one upon which the success of the undertaking greatly depends, is the projectile, or dart. It consists essentially of two parts, and while several different modifications have been tried, the principal features are alike in all of them. The forward part of the dart consists of a thin brass tube, into which the charge of dynamite is inserted. At the rear the tube is enclosed by a wooden plug, which flares out towards the rear until its diameter equals that of the bore of the gun. The forward end of the brass tube shows a mass of some soft material, into which is inserted a pin firmly held in place, the end being closed by a conical metal cap. Provision has also been made to allow a certain amount of air to act as a cushion for the dynamite cartridge, thus lessening the shock due to a sudden discharge. It is therefore claimed, that under ordinary circumstances there is little danger of the charge exploding,

since the pin cannot reach it and ignite the fulminate at its end ; but when thrown from the gun, the impact against a body will displace the soft material and drive the pin home, causing an explosion. Another feature of the projectile is the power which it possesses to correct, to a certain extent, the deflection due to a side wind. It will be noted, that with the present construction, the centre of gravity of the dart is some distance forward of its centre of figure. A side wind acting upon the lighter rear part would therefore have the tendency to deflect it so as to turn the head of the dart into the wind, which action would, in a measure, tend to keep it in the line of its trajectory.

The firing of the gun, if the expression may be used, is accomplished in the following manner: The dart is inserted in the breech, and a gas check placed in position ; a lever then being moved, the valve is opened and the air pressure admitted. This method of discharge will, it is thought, obviate the danger of the shock, which had heretofore proved a stumbling block to success ; and in addition, the valve-controlling mechanism is automatically arranged to admit the air, gently at first to overcome the inertia of the projectile, following with full pressure, and finally closing at the proper time as the dart leaves the gun.

Experiments made thus far have shown that the apparatus can be depended upon for a fair degree of accuracy and rapidity in firing. As regards the range attainable, the two-inch gun now being tested has attained $1\frac{1}{4}$ miles with a pressure of 420 pounds to the square inch. In the four and six-inch gun which are in course of construction, it is intended to use pressures of 2000 pounds and over, by the use of which they hoped to attain a range of three miles. Advantages claimed for these guns are lightness and ease of manufacture.

The Washington *Sunday Herald* of March 17, 1884, states that the experiments with dynamite shells have proved less efficient than was anticipated, as they have no penetration, and the explosion takes place on striking. The issue of March 30 narrates that a workman at the Delamater Works tried the 4-inch gun with a piece of cotton waste. Although only a 100 pounds pressure was put on, the waste was blown through a wooden door two inches thick, making quite a large breach.

The idea of employing the expansive force of steam, or of compressed air, for propelling projectiles is not a new one, but its application has not heretofore met with success, since penetration

has been sought for. Among other contributions to the subject is a paper "On the Numerical Expression of the Destructive Energy in the Explosions of Steam Boilers, and on its Comparison with the Destructive Energy of Gunpowder," by G. B. Airy, *Phil. Mag.* [4] **26**, 329, 1863. He reaches the conclusion that the destructive energy of one cubic foot of water, at the temperature which produces the pressure of 60 pounds to the square inch, is equal to that of one pound of gunpowder.

In Richardson & Watts' "Chemical Technology," Vol. I, Part IV, page 523, London, 1865, we also find the following: "High pressure steam is exceedingly well adapted to the performance of this kind of work; unluckily it would require high pressure steam of 400 atmospheres or 5000 lbs. pressure on the round inch to perform this duty, and as such steam could only be generated in a furnace intensely heated, it is scarcely probable that boilers will be found sufficiently strong and durable to work continuously under such pressure. If they were found to be practicable, nothing more would be necessary than to bring a steam pipe from the boiler to the breech of every gun in a fortress or a ship, and the admission of the charge of such steam into the chamber by a valve would be sufficient to discharge the missile of the 68-pounder with a speed of 1600 feet a second. The well-known Mr. Perkins studied this subject carefully, but applied it somewhat differently. He found that steam of this pressure could be generated only by water nearly red-hot; and instead of throwing the steam into the breech by a pipe, he threw the red-hot water into the breech of his gun, allowing it when there to expand itself into steam and expend its force in giving speed to the ball. This expedient of Perkins is well worthy of study. It has both the defects and advantages of a gunpowder gun. The red-hot water thrown into the barrel would have the fault of being too powerful at the beginning of its expansion and too weak at the end. The barrel would be filled partly with water and partly with steam; and as the water grew into steam it would lower its temperature and its pressure, so that the explosive force would fall off very much towards the end of the stroke. This is the inevitable evil of allowing the water to become vapor in the gun. When the steam is generated in a separate boiler, and freely admitted into the breech of the gun, there is reservoir enough of heat and steam to maintain the even pressure in following up the ball from the breech to the muzzle. It is the evil of charges converted into gas within the breech of the gun, that their temperature and pressure are too high at starting and too low at the

end. The steam-gun would in this respect be the best of our projectile forces.

“Compressed air has many of the advantages and some of the defects of steam; and the frequent use of the air-gun has shown its convenience as well as its efficiency. Air can be compressed into a reservoir by mechanical force, just as steam can be raised in a boiler by heat; and by compressing 400 times the natural quantity of air into a given space, a pressure of 400 atmospheres might possibly be obtained in this way. If an air pipe communicated from this reservoir to the breech of our gun, air of 400 atmospheres of pressure would certainly be able to follow up the 68-pounder shot, with pressure and velocity able to discharge it with a speed of 1600 feet per second, and, therefore, to do our work; but the apparatus would be full of mechanical difficulties.

“Liquid gases are known to be receptacles of enormous mechanical power. Carbonic acid gas, liquefied and shut up in a reservoir, generates large volumes of gas with great rapidity the moment it is permitted to expand. Other gases expand with still greater rapidity and force; and if we could conceive liquid gases to be easily made, safely carried, and comfortably handled, a charge of liquid gas bottled up in the breech of a gun would be a very effectual propelling power, and quite able to generate the force we want, and to apply it within the time we require. This system, however, is also beset with mechanical difficulties.

“The preceding illustrations of steam, compressed air, and liquid gases lead us on very instructively to the manner in which fire has become necessary to do the work of a gun. A supply of heat is essential to the expansion of a gas, and a rapid supply is indispensable to the rapid performance of the work. In steam, the fire is not only external to the gun, but external to the boiler in which the steam is generated. In gunpowder, the fire is introduced into the inside of the gun, for the purpose of supplying the heat that is wanted to raise the gases to their elastic pressure, and to maintain them at that pressure while expanding. Red-hot steam introduced into the breech of a gun rapidly cools down and loses its heat and power in expanding. If we could introduce fire into the breech of the gun at the same time, to maintain the heat of the steam and the water, the steam would become an admirable propelling force. Carbonic acid gas expanding rapidly from the liquid into the gaseous state cools down so suddenly as not only to lose its mechanical power, but to

freeze into solid flakes of snow. If we could charge the breech of the gun with fire as well as with liquid gas, the fire would give it the heat it wants, prevent its congelation and maintain its power to the end of the discharge. What gunpowder and gun-cotton do is really to provide a reservoir of gas and a fire to heat it simultaneously and in the same chamber. In the case of gunpowder the fire is fed with charcoal, in the case of gun-cotton the fire is fed with gun-cotton wool—another form of carbon. In gunpowder, large quantities of carbonic acid gas are generated, possibly in the liquid state, and are heated by the internal furnace of the charge, possibly red-hot. In like manner in a gun-cotton charge, red-hot water or steam is introduced with other gases, possibly also liquids, together with an internal furnace of flame; and thus the work is done—first, by the release of the gases themselves, and, secondly, by the continuance of the elasticity of those gases by the internal supply of heat. This is how gunpowder and gun-cotton really do the work of a steam-gun, a carbonic acid gun, or any other kind of gas gun.”

Prof. R. H. Thurston treats of the same subject in the *Jour. Frank. Inst.* **88**, 427, December 1884, under the title “Steam Boilers as Magazines of Explosive Energy,” and after referring to the above mentioned paper of Airy’s, and that of Rankine “On the Expansive Energy of Heated Water,” *Phil. Mag.* [4] **26**, 1863, he has computed, by the aid of the formulas of Rankine and Clausius, the magnitude of the quantities of energy residing in available form in both steam and water, for the whole usual range of temperatures and pressures familiar to the engineer, and also for those beyond, which have only been attained experimentally, but which are likely to be reached in the course of time, and he has plotted curves of the available energy of heated water, of latent heat and of steam, and the explosive energy of many different forms of boilers.

The dynamite air-gun is also described with illustrations, and discussed by Chas. E. Munroe in *Van Nostrand’s Eng. Mag.* **32**, 1, January, 1885, in a paper entitled “Some Recent Experiments on the Use of High Explosives for War Purposes.”

In determining the efficiency of the air-gun projectile against an armor-clad vessel, the author assumes that one of four effects may be produced, depending on the resistance of the armor to penetration, and on the material, thickness of wall, profile, weight and velocity of the projectile.

(1). The projectile may either penetrate the armor partially and explode in place, or pierce it completely and burst inside of the ship. This is the condition of greatest efficiency.

(2). It may explode immediately upon impact, and before breaking up. Then the explosive will exert the energy which it develops through explosion in a resisting receptacle.

(3). It may rebound before exploding. Then the effect will be reduced by the interposed cushion of air.

(4). It may break up on impact before the explosion takes place. Then the energy of the explosive will be simply that which it develops when exploded unconfined.

The resistance of an armor to penetration depends upon its hardness, its tensile strength (that due to bolting as well as that inherent in the metal itself), and its inertia. The latter is augmented by the thickness and weight of the armor, and by the rigid system of bracing which now obtains in practice. How great this resistance is can best be illustrated by an example. While, from the fact that very rapid progress is being made in the improvement of armor plates, we may have not chosen the best example, let us take the steel plates designed for the *Furieux*. One of these, weighing 23 tons, 9 cwt., and averaging over 17 inches in thickness, was tested at Gâvre, July 13, 1883. Three shots were fired against this plate from a 12.6-inch rifle using chilled iron projectiles, weighing 759 pounds each. The first and second shot struck with a velocity of 1403 feet each. The third struck with a velocity of 1438 feet. The projectiles were all broken up, all of the twenty bolts through the plate remained intact, and no portion of the plate fell from the backing, although it was somewhat indented and cracked.

Although we are not yet informed concerning the air-gun projectile, except for the weight given above and the pressure of the air also cited, yet when we remember that in the Gâvre experiments the pressure of the powder gas probably approached 40,000 pounds to the square inch, it is not unfair to infer that with a pressure of 500 pounds to the square inch a projectile will possess little or no penetrative power against the *Furieux* plates at a distance of $1\frac{1}{4}$ mile. Whether then the projectile would explode on impact or after rebounding, or whether it would break up before exploding, is a matter for speculation and conjecture. If the last condition prevails, then we can judge from some experiments recently made at the Naval Experimental Battery, what the destructive effect would probably be.

In these experiments Commander Folger detonated upwards of 400 pounds of dynamite, in charges of from 5 to 100 pounds, against a wrought-iron target, eleven inches thick, without damaging the plates. These charges were enclosed in cartridge bags and suspended against the plates. Commander Folger concludes from these experiments "that it is a matter which hardly admits of doubt, that a modern armor-clad will not be materially injured by the explosion, in superficial contact with her over-water plating, of charges of more than 100 pounds of dynamite."

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NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. IX.

The blowing up of Flood Rock was successfully accomplished October 10, 1885. The official report is not yet issued, and hence the following account has been compiled from various sources of information. Flood Rock had a superficial area of nine acres, about 250 square feet of which was above water. The rock consisted of hornblende gneiss, with intersecting cross-veins. A sea-wall seven feet high was built around the island, and two shafts were sunk, one sixty-seven and the other forty feet deep. The main shaft was used for removing the excavated rock in blasting out the headings. The smaller shaft was used for the tubes conveying the compressed air which drove the drills. The first series of headings branched out from the main shaft at a depth of forty feet, and from the bottom of the shaft another series diverged directly under those above. The headings branched at right angles every twenty feet, and were sixty in number in each tier. The double system of headings was employed to gain a sufficient depth after the explosion without the necessity of dredging out to the extent that was found necessary at Hallet's Point. The total length of tunneling was about four miles, consisting of twenty-four galleries running north and south and forty-six running east and west. The longest of these was 1200 feet in length, 6 feet wide and 10 feet high. There was a thickness of from 10 to 25 feet between the roof of the top tier of galleries and the water. There were 467 pillars left to support the roof; these were 15 feet square. The whole rock was honeycombed with tunnels, about 80,000 cubic feet of rock having been removed.

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars.

There were drilled in the pillars and roof 13,286 chambers for holding the cartridges, each chamber being three inches in diameter and about nine feet deep. These chambers were filled with rackarock* cartridges, of which there were about forty-seven thousand used, each being two and a half inches in diameter and two feet in length, and containing about six pounds of the explosive. In addition to the rackarock cartridges, several hundred ordinary dynamite cartridges were used, to which the wires leading to the firing batteries were attached. The shock resulting from the explosion of these dynamite cartridges caused the explosion of the rackarock. Upwards of two hundred and eighty-five thousand pounds of explosives were used in the charge.

The wiring in the mine was divided into thirty-six circuits, the batteries attached to these circuits being stowed in a tool-house on the rock. The wire of the primary circuit which actuated the electromagnet that closed the secondary circuits was led across to the Astoria shore on the morning of the explosion. The firing-key was about 1200 feet from the mine.

Two siphons, one twelve inches in diameter and the other three inches, were set at work at 10 A. M., October 9, flooding the mine, and they completed their work early the following day. The first effect of the explosion was to produce a rumbling noise, and then to project a mass of water over an area of about 1200 square feet to a height of about 150 feet. Masses of rock rose in the midst of this water to a height of from 40 to 50 feet. The explosion lasted about 30 seconds. As the water fell a dense cloud of yellowish smoke arose and floated over the Astoria shore.

Observations were made in many places, at various distances about the centre of the explosion, on the time of arrival of the terrestrial and aerial disturbances, and they showed that the terrestrial effect was apparent as far south as Princeton, N. Y., and as far east as Cambridge, Mass., and, as was to be expected, that the terrestrial impulse was in advance of the aerial, at least at the stations near at hand. The rate of transmission cannot be stated until these observations are reduced.

After the explosion the rock appeared undisturbed, though on close examination it was found to be somewhat fissured. However, it slowly settled, and by October 13 the entire rock was below water. It was not intended that the rock should be broken very fine, since

* Proc. Nav. Inst. 9, 755 ; 11, 281.

with the appliances at hand pieces of from ten to fifteen tons in weight could be most economically handled. The work has been in operation about nine years, and has cost upwards of 1,000,000 dollars. The cost of removing the broken rock is estimated at 600,000 dollars, and two years' steady labor will be required. The channel will then have a depth of 26 feet over an increased width of 600 feet.

In an interesting article in the *Jour. Military Service Inst. of the United States*, 6, 103, 1885, entitled "Recent Progress in High Explosives and their Uses in War," General H. L. Abbot, after resuming the results of recent experiments at Willet's Point, says the use of high explosives in shells, although attempted very shortly after the discovery of dynamite, is still in the experimental stage, because no certain mode of regulating the time of explosion has yet been discovered. When this has been accomplished, certain advantages will result. For field guns these advantages will chiefly come from thicker and heavier shells, broken into more numerous and regular fragments, and available for longer ranges than at present. For medium calibres, such as are used in sieges and bombardments, the shell capacity is necessarily too small to carry decisive charges, and the effects will be moral rather than physical. This is due to the intensely local action of these high explosives. The terrifying sound and frightful effect upon the object struck will perhaps appal new troops, but old soldiers will soon learn that the bark is worse than the bite. For the much larger calibres used in coast defence, it is stoutly claimed that charges of a size to be destructive in themselves may be employed even against armored ships; and experiments in this direction are now exciting so much interest that a brief résumé of what has been established both in respect to the possibility and to the utility of such firing, may not be unacceptable.

In Sweden,* in September, 1867, within a year of its invention, seventeen shells, each charged with 1.65 pounds of dynamite, were fired from an 18-pdr. howitzer loaded with about two pounds of gunpowder. No premature explosion occurred. In Norway* in the winter of 1870-71, some trials were made with a 6.8-inch Krupp gun. At first the shell was packed full of dynamite. Several preliminary shots were successful, but when the charge was increased to 1.65 pounds of gunpowder the shell burst in the bore. Continuing the same trials, shells filled with water, and primed with an ounce of dynamite

* Memorial de l'Officier du Genie, 20, 243 and 244.

in a copper extension of the fuze plug, were fired with full charges without accident. During the siege operations of the 2d Corps of the Army of Versailles,* in May, 1871, two shells charged with dynamite were fired without accident into the hostile lines; one was from a 24-pdr. howitzer and the other from a mortar. The dynamite was enclosed in a rubber bag held in position with gunpowder, and was ignited by a time-fuze in both instances.

These facts, and many others which might be cited, sufficiently prove that the use even of dynamite in shells has never been regarded as impossible; but the selection of a high explosive so sensitive to violent shocks, when others so much safer are known, is certainly not to be recommended at this late day.

Fairly successful trials with picric powder were made in England about fifteen years ago, but they were discontinued in consequence of the more favorable results with wet gun-cotton. The first trials with gun-cotton in the dry state were made many years ago, and a 7-inch Armstrong was thus burst by an explosion in the bore. Wet gun-cotton has succeeded better, and in England safety of firing and a good arrangement for effecting the explosion after impact are claimed. Folger's† successful experiments in firing gun-cotton are also cited, but the author regards those with explosive gelatine as more promising. "Should the trials with this fail, the Sprengel group will naturally receive attention. Gruson in Germany has been working in this direction for three or four years. He uses strong nitric acid in one compartment, and dinitrobenzol in another. The shock in the gun or the shock at impact, as desired, effects the combination, and explosion is caused by a fuze in the base of the shell.

"Assuming that artillerists will ultimately succeed in devising methods (1) for preventing premature explosions in the bore, and (2) for effecting explosion at the instant desired, the next question to decide is, what changes are needful to destroy the armor of modern ships of war. If this could be accomplished with moderate charges, armor-plating upon the sea would soon become as historical as the coats of mail in the Tower of London. But here an important distinction is to be observed. We already know that if the charge can be imbedded in the armor, quite moderate amounts will be effective. Popular belief attributes equal power to charges exploded in contact, or nearly so, with the plates at their outer surface. Unfortunately this is a grievous error."

* *Loc. cit.* p. 246.

† Van Nostrand's Eng. Mag. 32, 1, 1885.

The author then discusses the possibility of crushing the armor of a modern ship of war by means of exterior charges, using as his criterion the formula deduced by the Scandinavian Commission,* which he deems at present our safest guide when estimating the charges necessary to produce this effect, assuming them to be exploded in contact with the plating near or even below the water surface; and he concludes: "But what calibres of guns must we have to project the charges it indicates, varying from 80 pounds for 5-inch armor, to much larger amounts for that usually carried? The capacity of a 10-inch common shell is about 25 pounds; of a 12-inch common shell, about 40 pounds; and of a 16-inch common shell, such as is now fired from guns weighing 100 tons and upward, about 75 pounds. Battering projectiles for armor carry about one-third these weights. Clearly it is quite impossible to project the needful charges, and we have little hope either now or hereafter from exterior explosions against armor-plating. High explosives with all their wonderful power must either be carried deeply into the iron before explosion or they will fail to do much damage. But to secure this penetration, initial velocities of 2000 feet and the best steel shells thus far achieved are demanded; and even then guns of less calibre than 12 inches will be of little avail. Of course such a standard will have to be approached gradually in the trials; but by appreciating at the outset the full magnitude of the problem, unprofitable labor will doubtless be avoided."

In the same number of this Journal, p. 170, is an unsigned review of the article, by the compiler of these Notes, in *Van Nostrand's Eng. Mag.* 32, 1, 1885, in which, after practically admitting the conditions of efficiency as set forth by us, the writer adds, "Bearing in mind that the *muzzle energy* of the 100-ton gun is about 60,000 foot-tons, and that this appears to suffice to break up anything but the *thickest* steel armor, it is still an open question whether full penetration with a small charge (which is liable to simple ignition) is better than the full detonation on the surface of a much larger charge, that charge being, however, suitably *tamped* both by the character of its enveloping shell and several hundred foot-tons of remaining energy of the projectile upon striking. Even a partial initial penetration would use up some of this probable tamping due to its energy and lessen the effect on the target by the explosion.

* Proc. Nav. Inst. 7, 121, 1881.

"In a field so novel, experiment can only satisfactorily demonstrate the possibilities. So far, the simple placement of a large charge of dynamite against a heavy armor plate, and then exploding it, *entirely untamped*, does not appear to be conclusive as to what that same charge will accomplish when hurled against the plate with a striking energy of several hundred foot-tons, the charge being encased in a shell which affords some resistance to the initial bursting efforts of the gases evolved.

"Considering the very much greater potential of the explosive relative to the possible stored-up work of a projectile, and the undoubted loss of effectiveness on the target of the charge farthest removed, it is an open question whether it is best to use a hard and necessarily *thick* point (thus placing the charge farther away from the point of impact), or using a soft, *thin* point which will "squash-up" upon striking the target and bring the explosive in as close contact as possible.

"It will be seen that a wide field must be traversed before conclusions can be safely drawn. The experiments now in hand will, I trust, determine some of the mooted points. Much will be learnt that will enable us to make the most effective use of the high explosives against an enemy. If successful, we have available a weapon (the air-gun) which will be of value to us, in our present defenceless condition, as a possible stop-gap. Owing to its limitations of range it can never be considered a substitute for the heavy ordnance so much needed. But it will be at all times a valuable adjunct to our defensive appliances.

"It is possible that the *heaviest* armor may withstand the shock of an explosion of a shell containing 100 pounds of explosive gelatine. If that is the case, 500 pounds may be thrown, if required for the work. But it should be borne in mind that a vessel is protected in a very limited portion by this heaviest armor; that its decks, presenting the largest target, are very vulnerable, as was demonstrated by Lieutenant-Commander Folger with the assimilated deck target; that a still wider area of vulnerability is presented in an additional area of the water zone, 16 feet in width, surrounding the ship; if the explosion takes place within this zone, a few feet under the surface, the results are very likely to be fatal."

The writer then discusses the comparison made between the air-gun and the gun used in the Gâvre trials, and claims that the *mean* available pressures, and not the *maximum* pressure, in the gun-

powder gun should be taken as the standard for comparison. Estimating the mean pressure of the Gâvre gun as 12,000 pounds per square inch and the length as 16.1 calibres, while the pressure in the air-gun is 500 pounds to the square inch and its length 120 calibres, we should have a ratio of pressures for guns of equal length of 12000:3725. "But it is proposed to use (in the air-gun) an initial pressure of 2000 pounds, giving (with a flask or reservoir capacity of ten times the bore of the gun) a final pressure of 1820 pounds or a *mean* pressure of about 1910 pounds. With this pressure the comparison would be stated as 12000:14230 in favor of the air-gun, and the projectile from the latter would have the greatest penetrative ability."

The writer also notes that the projectile for the air-gun, as described, differs from that now in use. This is quite to be expected in a course of tentative experiments. He states too that in the firing of dynamite on iron plates, Lieutenant Zalinski used in the first experiment *ten* pounds of untamped dynamite cartridges, and in the second experiment *twenty* pounds of dynamite enclosed in an 8-inch wrought-iron pipe 30 inches in length, the charge being about 10 inches in height and the remainder of the pipe loosely filled with sand and debris.

At the Ann Arbor meeting of the American Association for the Advancement of Science, Commander T. F. Jewell, U. S. N., read a paper on the apparent resistance of a body of air to a change of shape, in which he described some experiments at the United States torpedo station, in which a disk of gun-cotton was exploded on a metal plate. Upon each disk of the explosive had been stamped the letters 'U. S. N,' and the year in which the material had been manufactured. After explosion upon the iron, similar indentations were found upon the plate, as if the air in the indented letters had been driven into the plate.*—*Science* 6, 207, Sept. 11, 1885.

In the *Proc. Am. Assoc. Adv. Science*, 33, 174, 1885, in a paper by Charles E. Munroe, entitled "Examination of methods proposed for rendering the lighter petroleum oils inexplusive," it is stated that, it having been seriously suggested that alum, sal ammoniac and camphor could be used to render the lighter petroleum oils inexplusive, and it having been found in practice that camphor did

* *Vide* Proc. U. S. Nav. Inst. 11, 110.

diminish very markedly the readiness with which explosive gelatine or gum dynamite could be exploded, the author has tested the effect of the above bodies by determining their solubility in benzoline; the flashing points of benzoline and commercial kerosene when treated with these bodies and when in their original state; and also the readiness with which mixtures of the oils, in the two conditions, with air could be exploded. The results showed that alum and sal ammoniac were practically insoluble in the oils and produced no effect upon them; that the camphor was soluble, one gram of benzoline dissolving about 1.5 gram of camphor; that an equal weight of camphor raised the flashing point of a kerosene 12° ; but that on the other hand the vapor of this camphorated kerosene, when mixed with air, exploded with greater readiness than the original kerosene.

The *Revue d'Artill.* **22**, 462, Aug., 1883, under the title, "The Use of Dynamite for Driving Piles," describes a process invented by M. Pradamovic, and put into execution at Pesth. On the centre of the head of the pile he fixes a circular iron plate 395 mm. in diameter and 117 mm. thick. On the centre of this plate he places a dynamite cartridge 157 mm. in diameter and 17.7 mm. high, and weighing 612.5 grams, wrapped in parchment paper. This is detonated by electricity. The effect produced under these conditions is equivalent to that obtained from five blows of a hammer weighing 1475 kilos. falling through three metres.

Gruson, Hellhof and Halbmayer have devised a time-fuze for projectiles, which is ignited by the resistance with which the projectile meets after it is set in motion. For this purpose advantage is taken of the heat produced by the chemical action of water or acid on metallic sodium or potassium. They are placed in separate vessels within the shell, and are brought in contact by the shock. The amount and position of the materials is so arranged that the maximum effect is attained only after a desired interval of time. (*Revue d'Artill.* **21**, 567, March, 1882.) The following note shows that the use of potassium as an igniter is not new.

The *Bib. Univ.*, Aug., 1831, describes the method employed by Engineer Lübke in blasting under water. A leaden tube, several feet long and closed at one end, was inserted in a hole in the rock, a cartridge was inserted in the bottom of the tube, and a piece of potassium placed upon the cartridge. The upper part of the tube

was funnel-shaped, and contained a thimble-shaped vessel filled with water, and supported in an upright position by a piece of touchwood, which, by a simple arrangement, would, when burnt, allow the thimble to overturn. The touchwood being set on fire, the workman rowed off to a safe distance and waited the event. The thimble being overturned, the water inflamed the potassium and the latter the powder. It was found that the powder must be very dry or the potassium would not inflame it. Common gunpowder was generally too damp — *Am. Jour. Science*, **22**, [1], 354, 1832.

E. Turpin, of Paris, has recently patented in England an explosive formed by mixing 80 parts of potassium chlorate with 20 parts of gas tar which contains from 1 to 10 per cent. of an absorptive substance such as infusorial earth, charcoal, and the like. One part of the chlorate can be replaced by permanganate. — *Bericht. Deutsch. Chem. Gesell.* No. 1, 1884, Patente 35.

In an abstract from the *J. Soc. Ch. Ind.* **3**, No. 2, 132, describing kieselguhr and its practical applications, it is said that the finest earth is found at Traterleuss, between Hamburg and Hanover, Germany. From this dynamite has been made containing 82 per cent. of nitroglycerine. It has been used for the purpose of disinfection, in the form of sticks saturated with bromine, and a patent has been taken out for the use of kieselguhr as an absorbent for concentrated sulphuric acid to facilitate transportation without leakage or loss. When the acid is desired for use it is to be extracted by water. — *J. Am. Chem. Soc.* **6**, 140, April, 1884.

According to the *Annales Industrielles*, M. Michalowski, an engineer at Montceau-les-Mines, has invented a new explosive. It is a powder with a density little more than half as great as that of ordinary powder, with irregular grains of a slate-gray color. It does not explode by the action of fire, and detonates only under a blow, like dynamite. — *Jour. Frank. Inst.* **87**, 315, 1884.

The London *Times* announces that a new explosive,* known as hellhoffite, which has been invented by Hellhoff and Gruson, has been subjected to comparative trials at St. Petersburg, together with nitroglycerine and ordinary gunpowder. It is a solution of a "nitrated organic compound (naphthalene, phenol, benzene, and the like), in fuming nitric acid. In preparing the hellhoffite tried in the experi-

* *Proc. Nav. Inst.* **8**, 450.

ments, dinitro-benzene, a solid, inexplosive, and badly burning body, was used. At the first trial glass bottles of 20 cubic centimetres each, were filled with 20 grams of the respective explosive substances and corked. A primer of fulminate of mercury was passed through the cork, a slow match being attached to the outer end of the tube for the purpose of ignition. Each of the bottles thus prepared was placed on a truncated cone of lead, the upper diameter of which was 3.5 centimetres, its lower 4.5, and its height 6. The cone itself stood on a cast-iron plate 2.5 centimetres thick. The deformation of the leaden cone by the action of the explosives could consequently be taken as a measure of their respective destructive power. The explosion of the gunpowder, as was anticipated, caused no changes. By the explosion of the nitro-glycerine the cone was compressed about a quarter of its height; its surface had assumed the appearance of a well-worn hammer: the diameter of the surface had been increased to 5.5 centimetres. The explosion of the hellhoffite caused much greater changes. The surface of the cone was completely torn; pieces five centimetres long and two centimetres thick were torn off and thrown about for several paces; only half of the cone was still a compact but entirely defaced mass. At the second experiment bottles (of 25 grams each) filled with the various explosive substances were let into corresponding cavities bored into the face of fir blocks of similar dimensions. In exploding the gunpowder the block was torn into four pieces as if split with a hatchet, the several pieces were thrown about for 18, 12, 11, and 10 paces. In exploding the nitro-glycerine the block was split into several pieces. The upper portion of the block, as far as the bottle was let into it, was torn off transversely to the direction of the fibre in such a manner that a smooth cut was formed. The explosion of the hellhoffite likewise tore the portion of the block surrounding the bottle transversely to the direction of the fibre, and splintered the remainder of the block into a large number of thin fibres. The following experiments were also made with hellhoffite alone. A slow match was passed through the cork, as far as the surface of the hellhoffite in the glass bottle; no explosion followed on igniting the slow match. A quantity of hellhoffite poured into a bowl could not be exploded by a lighted match. Finally, a few drops of hellhoffite were poured on an anvil and exposed to heavy blows with a hammer, and no explosion followed. The hellhoffite, consequently, possesses the following advantages: (1) When detonated by fulminate of mercury it acts more powerfully than nitro-glycerine;

(2) it may be stored and transported with perfect safety as regards concussion, as it cannot be exploded either by a blow or a shock, nor by an open flame. On the other hand, it has the following disadvantages: (1) Hellhoffite is a liquid; (2) the fuming nitric acid contained in hellhoffite is so volatile that it can be stored only in perfectly closed vessels; (3) hellhoffite is rendered completely in-explosive by being mixed with water, and consequently cannot be employed for works under water.

In General Abbot's *Report on Submarine Mines*, page 252, it is stated that "Franklin in his *Letters on Electricity* (June 29, 1751), was the first to suggest the employment of frictional electricity for ignition of gunpowder. In 1831, Moses Shaw, of New York, made the first actual application of this method to the explosion of mines. The practical difficulties arising at that date from defective insulation of the apparatus, and especially of the leading wires, were so serious that attention was directed to the heating of a fine platinum wire by a current of voltaic electricity, and that method soon superseded all others. A sketch, found among the papers of the late Samuel Colt, of Hartford, which bears date of 1836, indicates a method of firing the torpedoes at will, by the use of a fine platinum wire to be heated by a battery; and in his grand experiment upon the Potomac in 1843 he blew up a brig under full sail with a battery placed in Alexandria, five miles distant. The first application of electrical ignition in civil engineering was made by Sir Charles Pasley of the Royal Engineers, who, in 1839, successfully used low tension fuzes in the removal of the wreck of the Royal George at Spithead. He employed a form of the Daniell battery—which was invented by Becquerel in 1829, and reinvented by Daniell in 1836."

In the historical address delivered by Sir Frederick Abel before the Institution of Civil Engineers, and reprinted in these Proceedings,* under the title "Electricity Applied to Explosive Purposes," no reference is made to Colt's experiments, and it is stated that "the first practical application of the voltaic battery in this direction was made about forty-five years ago (1838), by French military engineers," but otherwise he agrees with Abbot. Both of these authorities, however, seem to be unacquainted with the researches of Dr. Robert Hare, of the University of Pennsylvania.

The facts seem to be that Mr. Moses Shaw, having frequently failed

* 9, 767, 1883.

in his efforts to blast rocks by the use of a frictional electric machine, applied June 1, 1831, to Dr. Hare for advice and assistance in perfecting his invention. As Dr. Hare had long used his famous deflagrator* (or voltaic battery) in his eudiometrical experiments to ignite explosive gaseous mixtures, it occurred to him that it could be equally well used for firing gunpowder, and his experiments proved his belief well founded, for he succeeded in firing twelve charges of gunpowder simultaneously at a distance of one hundred and thirty feet from the battery, and he held that "there are no limits to the number of charges which may be thus ignited, excepting those assigned by economy to the size of the apparatus employed." He also added that "it must be obvious that in all cases of blasting under water, the plan of the tin tubes, and ignition by a galvanic (voltaic) circuit, must be very eligible." The igniting wire was of the "smallest size used for wire gauze." The details of these experiments, with method of preparing the cartridges, etc., are given in *Am. Jour. Sci.* [1], 21, 139, August, 1831, under the title, "On the Application of Galvanic Ignition in Rock Blasting."

The use of water in connection with blasting in mines and quarries is said to be rapidly extending in this country and in Europe. A tube filled with water is inserted in the bore hole next the powder cartridge, the tube being of thin plate, or even of paper. The usual tamping follows, and when the explosion occurs the tube containing the water is burst, the explosive efficiency being increased by the presence of the water, and the effect extended over the enlarged interior of the bore hole due to the space occupied by the water-tube. A much larger quantity of the material to be mined or quarried is thereby brought down or loosened with a given quantity of the explosive, while the heat of the explosion converts a portion of the water into steam, which, with the remaining water, extinguishes the flame and absorbs and neutralizes the gases and smoke generated.

The Boston *Journal* of June 30, 1885, records a curious explosion which occurred in Brookline, Mass. On the preceding Sunday a resident of Brookline returned his watch to his pocket rather quickly, and was startled by an explosion, which was followed by others in rapid succession. Before he could remove his clothing it had been burned through to the flesh, making a painful wound. The hand in

* Ganot's Physics (ed. 1883), p. 728.

which he held the watch was also severely burned. An examination proved the explosion to have been caused by chlorate of potash tablets, which the gentleman was in the habit of carrying loose in his pocket, and which were ignited by the watch being dropped quickly upon them. The composition of troches of chlorate of potassium, according to *Parrish's Treatise on Pharmacy*, p. 880, 1884, is

Chlorate of potassium,	32.50 grams.
Sugar,	124.00
Tragacanth,	6.50
Spirit of lemon,	.65

and manufacturers are warned to avoid trituration and pressure in order to prevent the mixture from igniting or exploding.

U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. X.

Among our new exchanges we are pleased to note the *Transactions of the Technical Society of the Pacific Coast*, published in San Francisco, Cal. The society was instituted April, 1884, with Colonel Geo. H. Mendell, U. S. A., as president, and has already entered upon the publication of the second volume of its transactions. Besides other papers of interest, we find several devoted to the subject of explosives. Thus Dr. Fred. H. Jenssen treats of the "Causes of Explosions in the Manufacture of High Explosives," I, 200; 1884, and finds that these may, in general, be traced to—1. improper construction and faulty arrangement of the works and machines; 2. carelessness on the part of the workmen; 3. maliciousness. Under the first head, he considers the relative dangers of the two principal processes, Nobel's and Mowbray's, for the manufacture of nitroglycerin. He employs in his own practice two Nobel apparatus, having a productive capacity of one ton, built side by side. By this means, three men can run the works and produce six to eight tons of nitroglycerin daily, while a few laborers are engaged on outside work. After the danger of firing in the converter, comes that from overheating when the nitroglycerin is precipitated. As the acid nitroglycerin is very sensitive and decomposes at 100° F., it is essential that the charge in the converter should be run into a very large body of water, and that this water should be changed as soon as possible. Under no circumstances should acid nitroglycerin be stored over-night. Care should be taken that the pipe lines between

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars.

the tanks do not cross or approach near steam or hot-water pipes. Accidents arise from the wash waters, since they carry nitroglycerin partly in suspension and partly attached to the solid impurities in the water. For economy's sake, as well as to avoid accidents, arrangements should be made to catch as much of this as possible before discharging the water; but where the water is run off, it should be led through earthenware or lead pipe by the shortest line to the river, bay or well. If wooden conduits are used, they become saturated with nitroglycerin and acids. Hence they should be well covered to protect them from the sun, which causes decomposition. The effect of the sun's rays was seen at one factory where no provision had been made to catch the traces of nitroglycerin, and where the wash waters ran a short distance over a sandy beach before entering the river. The result was that on a hot summer's day red fumes were observed rising from the ground, and a heavy explosion soon occurred. Even where wells are used, there is danger from these wash waters. For instance, at a factory where these waters were led through a ditch in rocky ground, it was found that considerable quantities of the explosive had accumulated in the fissures in the rock. Numerous unsuccessful efforts were made to remove this, and finally the ditch was dammed, so as to keep the explosive covered with water. Several years after, the ditch was struck by lightning, and an explosion ensued which damaged the buildings in the vicinity severely and hurled large masses of the rock to considerable distances. From the sensitive nature of acid nitroglycerin, it naturally follows that the recovery of the spent acids is attended with great danger.

In the making of the dynamite, there is little danger if the absorbent is itself a safe one, and is not too warm, and the proper precautions regarding the use of metal tools are taken. The buildings should be heated by hot water or steam, and the pipes so covered as to prevent the dust from settling upon them, or, if it does settle, they should be frequently cleaned. This dust is a constant source of danger, especially in the making of explosive gelatine, where nitro-cellulose is used in the dry state and finely pulverized. In all the rooms, the windows should be shaded to prevent the direct sunlight from falling on the explosive. Similar precautions are to be taken in the packing department; and here the author describes the devices which may be safely used.

The last two causes are discussed at length, and among instances

of maliciousness, the writer cites one from his own experience where a quantity of tips from phosphorus matches were placed in a bag of infusorial earth, and were not discovered until the earth had been made up into dynamite. The essay is a practical one, by a man of many years' experience, and deserves more space than we can give it. It was followed by a discussion, which is printed in the *Trans.* **2**, 16; 1886.

"A Talk about Explosives," by Wm. R. Quinan, **2**, 109; 1886, gives a brief historical survey of the development of gunpowder, and of the growth of the explosive industry on the Pacific Coast; it then describes various explosive compounds and mixtures, and discusses their mode of action and efficiency, and concludes with a résumé of portions of Berthelot's thermo-chemical researches, and of Debus' * paper on the chemical theory of gunpowder.

The most novel among these essays is that by L. J. Le Conte, **2**, 223; 1885, bearing the title "Are Not Dynamite Catastrophes Intimately Associated with Electric Phenomena?" The author has for the past ten years noted the circumstances attending the accidental explosions which so frequently occur on the Pacific Coast, and he has found that, with the exception of such explosions as occur during thunderstorms, these explosions take place during the violent, desiccating north-wind storms peculiar to the winter and spring months in California, but occasionally happening in midsummer. These winds have a velocity of fifty miles per hour, and a relative humidity of about 20 per cent., but frequently as low as 15 per cent., though seldom as low as 5 per cent. During the prevalence of these winds a prodigious amount of electricity is developed by the friction of clothing, especially when walking against the wind. One can thus easily generate a spark *half an inch long*. The phenomenon is also strongly marked in horses at work, the electricity causing their manes and tails to bristle to a remarkable extent. The author finds in this electricity the exciting cause of these explosions, and in the *dust* that prevails in the works, the medium through which explosion is propagated, a dust explosion always preceding the explosion of the mass of powder. These explosions occur on the third or fourth day of the storm. To test his theory, the author made four predictions in 1882 and 1883, and in each case an explosion of considerable magni-

* Proc. Nav. Inst. **9**, 1, 1883.

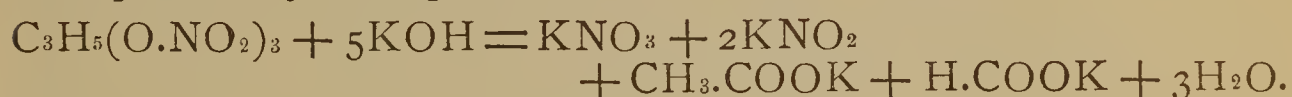
tude occurred. To guard against these accidents, the author suggests the use of steam jets, such as have been so successfully applied in cotton and flour mills and in coal mines.

The author believes that explosions during thunderstorms are caused by the *return shock*, and hence he considers it a fundamental precaution that all good conductors of electricity should be prohibited from entering any building where explosives are stored or manufactured, and believes it would be a wholesome rule not to allow such conductors to be anywhere near the premises.

M. Hay and O. Masson have studied the "Elementary Composition of Nitroglycerol"—*Proc. Roy. Soc. Edin.* 32, 87. After reference to former work on nitroglycerol by Williamson and others, the authors detail their process for preparing the compound. One part by weight of pure glycerol was added drop by drop to 2 parts nitric acid (1.49) and 6 parts sulphuric acid (sp. gr. 1.84), the two being kept below 10°. After ten minutes the mixture was thrown into water, and the precipitated oil was well washed and dried at 60–80°, finally being kept in a vacuum for twelve days over sulphuric acid, sp. gr. at 14.5° = 1.601. The combustion was made by weighing out 0.2 — 0.4 gram into a porcelain boat containing fine copper oxide, and then adding another layer of the oxide. After the boat had been introduced into the combustion tube, its contents were thoroughly mixed with the oxide in the tube; then the combustion was proceeded with in the ordinary way. Nitrogen determinations were 18.25 and 18.06 (theory 18.5). Difference in preparation does not cause a difference in composition. From these results and those obtained by Hay (next abstract), the authors conclude that the generally accepted constitution of trinitroglycerol is correct.

M. Hay gives in the *Trans. Roy. Soc. Edin.* 32, 67, the results of his study of the "Chemistry of Nitroglycerol." From the resemblance of nitroglycerol to the nitrites in its physiological and therapeutical properties, the author was at first inclined to regard it as being a glyceryl nitrite instead of a nitrate, but the result of a further investigation did not confirm this view. Railton and others have stated that nitroglycerol when treated with alcoholic potash yields glycerol and potassium nitrate. The statement is incorrect: the decomposition is of a complex nature. No glycerol is obtained, as it is oxidized at the expense of the NO₂ groups, about two-thirds of which suffer

reduction to the nitrous condition, only about one-third being found as nitrate at the end of the reaction. The other products of the reaction are potassium acetate, oxalate and formate, a small amount of ammonia, and a reddish-brown resinous substance, which gives a dark color to the liquid. Numerous determinations of the amount of nitrite formed showed that 100 parts of nitroglycerol gave from 34.14 to 35.24 parts of nitrous anhydride. (If two-thirds of the nitrogen were converted into nitrous anhydride, the amount would be 33.48.) As it was also found that 5 mols. of potash were required to decompose 1 mol. of nitroglycerol, it seems that the principal reaction may be expressed by the equation



The reaction is the same with either alcoholic or aqueous potash, but it is very slow in the latter case, owing to the sparing solubility of nitroglycerol in water.

Ammonia and alkaline carbonates act in a manner similar to potash. The same may be said for sodium hydrogen phosphate, but the reaction is much less powerful, whilst sodium chloride exerts hardly any action. Hydrochloric acid acts less powerfully than alkaline carbonates, and sulphuric acid (1:10) less powerfully still, whilst the concentrated acid has no action. De Vrij's statement that nitroglycerol is decomposed by sulphuretted hydrogen is not correct. The alkaline sulphides decompose nitroglycerol, sulphur being precipitated, and the reaction is rapid, and seems to be promoted by the sulphur; yet the particular part played by that element has not been ascertained. Hot water decomposes nitroglycerol slowly. The amount of glycerol formed from a given weight of glycerol agrees fairly with the assumption of its being glyceryl trinitrate.

As different statements have been made as to the physical characters of nitroglycerol, the author has prepared it in a state of purity, and finds that it is perfectly colorless, and remains so even when exposed to air. It keeps equally well in water or alcohol. Heated on the water-bath, no change occurs unless acids or alkalis are present.

1 gram of nitroglycerol dissolves in 800 cm. of water; in 10.5 cm. alcohol (sp. gr. 0.846); in 1 cm. methyl alcohol (sp. gr. 0.814); in 4 cm. methylated spirits (sp. gr. 0.830); in 18 cm. amyl alcohol; in less than 1 cm. benzene; in 120 cm. carbon bisulphide; in all proportions in ether, chloroform, glacial acetic acid and phenol, and sparingly in glycerol.

Nitroglycerol can be estimated with tolerable accuracy by determining the amount of nitrite formed by boiling with alcoholic potash, and assuming that 100 parts of nitroglycerol yield 33.48 parts of nitrous anhydride. (*Abst. Jour. Chem. Soc.* p. 742, *July*, 1885.)

The "Physiological Action of Nitroglycerol" has been studied by M. Hay (*Chem. Centr.* 108, 1884), and he states that the poisonous action of nitroglycerol cannot be explained by the action of its constituents. The symptoms are similar to those produced by amyl and potassium nitrites. The author found that, of the three NO_3 groups present in nitroglycerol, only one is removed by the action of alkalis as nitrate, the other two combining with the alkali as nitrite, whilst the oxygen set free oxidizes the regenerated glycerol. An alcoholic nitroglycerol solution reacts rapidly in this sense with an alcoholic sodium hydroxide solution, with development of much heat. The formation of nitrite, however, occurs even on digesting at 40° an aqueous solution of nitroglycerol (1:800) with a little sodium hydroxide (0.2 per cent.), the reaction being complete in about ten minutes.

Blood at the temperature of the body acts similarly upon nitroglycerol: the blood becomes chocolate-colored, as is the case when it is exposed to the action of amyl or potassium nitrite. Spectroscopic observation reveals the metahaemoglobin band. Reducing agents reproduce the red color of haemoglobin, as in the case of the nitrites above mentioned. Hence nitroglycerol acts by its conversion into nitrite. (*Abst. Jour. Chem. Soc.* p. 681, *June*, 1885.)

In the course of their researches on the heat-relations of the explosion of gaseous mixtures (*Ann. Chim. Phys.* 4 [6], 66, *Jan.*, 1885), Berthelot and Vieille have been able to obtain the specific heat of the elementary gases at high temperatures. The experimental data were obtained by the combustion of cyanogen mixed with sufficient oxygen to convert it into carbon monoxide and nitrogen—two gases which have sensibly the same specific heat. From the pressure developed in the explosion, the temperature referred to the air thermometer was calculated; and from the total quantity of heat produced, and the temperature, the specific heat (at constant volume) of the resulting gaseous mixture was derived, and hence the specific heat of either of the resulting gases. The results of six experiments of this sort were as follows:

Mixtures.	Pressure developed atm.	Heat evolved.	Temperature.	Specific Heat. Total. For N ₂ and CO.	
C ₂ N ₂ + O ₂	25.11	126,500 cal.	4394°	28.81	9.60
C ₂ N ₂ + O ₂ + 1½N ₂	20.67	126,500	4024	31.46	8.39
C ₂ N ₂ + O ₂ + 2N ₂	15.26	126,500	3191	39.67	7.93
C ₂ N ₂ + O ₂ + $\frac{7.9}{2.1}$ N ₂	11.78	126,500	2810	45.05	6.67
C ₂ N ₂ + 2NO	23.34	169,800	4309	39.39	9.85
C ₂ N ₂ + 2N ₂ O	26.02	168,400	3993	42.17	8.43

It will be noticed that the numbers obtained are closely identical, whether oxygen, nitrogen monoxide or dioxide, is used to effect the combustion; thus, at 4400° the specific heat with oxygen is 9.60 and with nitrogen dioxide 9.85, the ratio of N to CO being 1:1 by volume. At 4000°, with oxygen, the specific heat was found to be 8.39, and with nitrogen monoxide 8.43, the ratio of N to CO being 3:2 by volume. Moreover, it will be observed that the specific heat increases rapidly with the temperature. This increase may be expressed as a function of the temperature by the empirical formula

$$C = 6.7 + 0.0016 (T - 2800),$$

giving the following calculated values: at 2800°, 6.7; 3200°, 7.3; 4000°, 8.6, and 4400°, 9.3, the observed numbers being 6.7, 7.9, 8.4 and 9.6 respectively. These numbers may be adopted as expressing, at high temperatures and constant volume, the molecular specific heat of the simple gases N₂, H₂ and O₂, as well as of the compound gas CO, which is closely related to them. It is therefore evident that in passing from 0° to 4500° the mean specific heat of the elementary and simple gases nearly doubles. There is, however, another group of elementary and of compound gases to be considered. Regnault showed that the specific heat of chlorine, bromine and iodine was higher than that of the other elements, being 6.6 at constant volume, instead of 4.8. The remarkable fact is that this specific heat is closely the same as that of the compound gases which are formed with a contraction of one-third in volume, as water, nitrogen monoxide and carbon dioxide. The data were obtained by combining chlorine and hydrogen in presence of an excess of one or the other of these gases; from which it appeared that the weight $\frac{2}{3}$ Cl was sensibly equal to that of H₂. The mean specific heat of chlorine at constant volume was found to be at 1800°, nearly three times that of hydrogen, the latter being 5.1, and the former 15.3, nearly. Chlorine comports itself toward oxygen as ozone would do if it were stable and were formed with the evolution of heat.

In a second paper (*loc. cit.* 77), these authors have given the results of similar calculations to determine the mean molecular specific heat of water and of carbon dioxide at high temperatures. The hydrogen was burned either with oxygen alone or with oxygen mixed with nitrogen; in the latter case, the specific heat of the nitrogen was subtracted. The following data were thus obtained:

Mixture.	T.	Total Specific Heat.	Specific Heat of the N.	Mean Molecular Specific Heat of H_2O between 0° and T° .
$H_2 + O$	3240°	18.12		18.12
$H_2 + O + \frac{1}{2} N$	2860	20.52	1.69	18.83
$H_2 + O + N_2$	2543	23.08	6.26	16.82
$H_2 + O + 2N_2$	2180	26.93	11.36	15.57
$H_2 + O + 3N_2$	1798	32.05	15.21	16.84
$H_2 + N_2O$	3133	25.09	7.20	17.89
$H_2 + N_2O + N_2$	2601	30.60	12.70	17.90

The value given in the fifth experiment is not regarded as reliable as the others, since the large amount of inert gas present caused the combustion to be twelve times as slow. It will be observed that here also the specific heat increases with the temperature. The authors represent this increase by the empirical formula

$$C = 16.2 + 0.0019 (T - 2000).$$

Since the mean specific heat of water-vapor between 130° and 230° is 6.65 at constant volume, it appears that it is more than doubled at 2000° , and tripled at 4000° . On comparing the elementary specific heat of the vapor of water with that of its constituent elements, it appears that the former value is in excess of the latter at 2000° by 7.0, and at 4000° by 5.1. This excess represents a double work—first, that of the molecular disaggregation of the compound gas, and secondly that of its chemical dissociation. The values obtained for carbon dioxide are given as follows:

Mixture.	T.	Total Specific Heat.	Specific Heat of the N.	Specific Heat of the CO_2 .
$CO + O$	3334°	20.40		20.40
$CO + O + N$	2840	24.02	3.36	20.66
$CO + O + N_2$	2548	26.69	6.27	20.42
$CO + O + N_5$	1807	37.47	12.67	24.80
$C_2N_2 + O_4$	4862	54.00	10.00	22.00
$C_2N_2 + O_4 + N_2$	4082	64.31	17.50	23.40
$C_2N_2 + 4N_2O$	3972	86.71	42.70	22.00

The fourth of these results is inaccurate, owing to the extreme slowness of the combustion. The results with CO give a mean value of 20.5 between 0° and 2900°; those with CN give 22.5 between 0° and 4300°. Taking them together, they may be represented by the empirical formula

$$C = 19.1 + 0.0015(T - 2000).$$

This gives for the elementary specific heat of carbon dioxide at 2000°, 19.1; at 3000°, 22.1, and at 4000°, 25.1. The mean specific heat of this gas, therefore, more than triples, and the elementary specific heat quadruples, between 0° and 4300°. (*Abst. Am. Jour. Sci.* 29, 331; 1885.)

Two difficulties attend the determination of the heat of combustion of carbon and its compounds: one arises from the length of time required, the other from the incompleteness of its oxidation. Berthelot and Vieille have obviated these difficulties by effecting the combustion in oxygen compressed to about seven atmospheres, in a calorimetric bomb; using a weight of combustible such that the oxygen consumed by it does not exceed 30 to 40 per cent. of the whole quantity. The ignition is accomplished by a platinum wire heated to redness by electricity, and is completed in a few seconds, sometimes with the characteristic noise given by an explosion in a closed vessel. The entire operation does not require more than three or four minutes, and is applicable to all substances whose vapor tension at the ordinary temperature is inconsiderable. The completeness of the combustion was verified by an examination of the products. The heat of combustion thus obtained is, of course, the heat at constant volume. For carbon this is the same value as that at constant pressure, since the carbon dioxide formed replaces the oxygen volume for volume. For hydrogen compounds, however, the usual corrections are necessary for the condensation of the water-vapor. When cellulose in the form of cotton was burned in this way, the ash being deducted, one gram gave 4.2 calories; or one equivalent (162 grams) 680.4 calories. The heat of combustion, calculated at constant pressure, the water being in the liquid state, is 681.8 calories. Comparing this value with that of the carbon contained in the cellulose (referred to diamond), 564 calories, it appears that that of the cellulose is in the excess 117.8 calories, or about one-fifth. It follows from this that the hydrates of carbon, so-called, contain an excess of energy above that given by the carbon and water which their decomposition would

furnish. The authors call attention to the fact that this is also true of incompletely burned charcoal, as, for example, the *charbon roux* used in making gunpowder; and hence that the energy of a sample of gunpowder due to the carbon it contains cannot be accurately calculated from its percentage composition. (*Bull. Soc. Ch.* **43** [2] 262, *Mar.*, 1885; *Abst. Am. J. Sci.* **30** [3,] 154; 1885.)

In order to determine the rate of transmission of the explosive wave in solid and liquid explosives, Berthelot (*Compt. rend.* **100**, 314; 1885) detonated them in tubes of lead, tin or Britannia metal, 1–2 mm. in internal diameter and 100 to 200 metres long. The explosives employed were pulverulent or granulated gun-cotton, xyloidin, nitromannitol, nitroglycerol, dynamite and panclostite. The results show that as a rule the rate of propagation of the explosive wave increases with the density of loading, and also, for tubes of the diameters employed, with the diameter of the tube. It also seems to increase with the resistance of the material of which the tube is composed. The detonation shatters the tube in which the explosive is contained, and in this respect the experiments differ from those in which the explosives are gaseous. The results were sensibly the same whether the tubes were bent or straight.

With compressed pulverulent gun-cotton, the mean velocity of the explosive wave is about 5200 m. per second in lead tubes, and about 6000 m. per second in tin tubes. Granulated gun-cotton with a density of 1.1–1.3 gave a velocity of about 5000 m. Xyloidin gave similar results. Nitromannitol gives a still higher velocity, granulated nitromannitol of density 1.9 giving the highest observed velocity, 7686 m. per second. With nitroglycerol in tubes 3 mm. diameter the rate of transmission is lower, and varies between 1078 and 1386 m., according to the conditions. Dynamite in tubes 3 mm. in diameter gave a velocity of 2333–2753 m., and in tubes 6 mm. diameter an average of 2668 m. Panclostite gave results similar to those obtained with gun-cotton.

Berthelot finds (*Compt. rend.* **100**, 1326; 1885) that when gunpowder is dried by stoving, in the usual way, at 60°–65°, a peculiar odor is obtained. This smell is due to the sublimation of sulphur, which also carries with it small quantities of the non-volatile constituents of gunpowder. A quantity of the sublimate condensed and collected on plates of glass had the composition: sulphur 97.84,

potassium nitrate 0.90, charcoal, etc., $1.26 = 100$. The vapor tension corresponding to this sublimation is too small to be measured.

Among other substances produced by P. Griess in his researches on the "Diazo Compounds," are azonitromethanebenzoic acid, $\text{COOH.C}_6\text{H}_4.\text{N}_2.\text{CH}_2.\text{NO}_2$, and azoacetoaceticbenzoic acid, $\text{COOH.C}_6\text{H}_4.\text{N}_2.\text{CHAc.COOH}$. The former is obtained by mixing an aqueous solution of pure metadiazobenzoic acid nitrate with a dilute solution of nitromethane in an excess of potash, and after a short time adding hydrochloric acid, when the pure acid is thrown down as a yellowish-red precipitate. It is moderately soluble in boiling alcohol and ether; very sparingly in boiling water; is almost tasteless, and detonates when heated. Its ammoniacal solution gives a deep red-colored precipitate with silver nitrate, and no precipitate with barium chloride.

The second compound is formed by the action of metadiazobenzoic acid sulphate on ethyl acetoacetate. It is almost insoluble in boiling water, readily soluble in hot alcohol, from which it crystallizes in small scales or needles which have a bitter taste. When cautiously heated it melts, and at a higher temperature detonates, leaving a carbonaceous residue. The silver salt forms a bright yellow, amorphous precipitate. (*Berich. Berl. Chem. Ges.* 18, 960; 1885.)

A. Smolka states (*Monatsch. Chem.* 6, 198) that when ammonia is added to an aqueous solution containing lead nitrate and mannitol in the proportion of 2 mols. of the former to not less than 1 mol. of the latter, a mannitol lead nitrate having the composition $\text{C}_6\text{H}_8\text{O}_6\text{Pb}_4(\text{NO}_3)_2$ is precipitated. This substance is sparingly soluble in water and insoluble in alcohol. It detonates when suddenly heated. The nitric acid in the compound is not eliminated by treatment with ammonia. (*Abst. Chem. Soc. Jour.*, July, 1885.)

In the study of the "Polyacetylene Compounds," A. Baeyer finds (*Berich. Berl. Chem. Ges.* 18, 674; 1885) that diacetylenedicarboxylic acid, $\text{COOH.C} : \text{C.C} : \text{C.COOH}$, is obtained by oxidation of the copper compound of ethyl propargylate with an alkaline solution of potassium ferrocyanide. It crystallizes with one mol. H_2O in rhombic tables or needles; it turns brown at 100° , and explodes violently at about 177° . This seems to be the first instance of an explosive substance containing carbon, hydrogen and oxygen only. On

exposure to light, the acid at first assumes a deep rose color; on longer exposure it is converted into a purple-red mass. It is readily soluble in ether, alcohol and chloroform, moderately in water, very sparingly in light petroleum and benzene. With an ammoniacal copper solution, the aqueous solution gives a brownish-red precipitate; with silver nitrate, a white turbidity. In a subsequent paper (*loc. cit.* 18, 2269; 1885) the author finds that a better yield of the diacetylenedicarboxylic acid is obtained if free propargylic acid is employed for its preparation, instead of the ethyl salt.

The alkaline copper compound yields tetracetyleneolicarboxylic acid, $\text{COOH.C : C.C : C.C : C.C : C.COOH}$, when oxidized with potassium ferrocyanide. This forms fine, colorless needles which blacken quickly even when protected from light. It is extremely explosive, and yields sebacic acid when reduced.

By warming ammonium diacetylenedicarboxylate with cuprous chloride at 30° , a reddish-violet precipitate of the copper compound of diacetylene is formed, and this, when heated with a concentrated solution of potassium cyanide, yields a gas which has an odor somewhat like dipropargyl, and which, when passed through an ammoniacal solution of cuprous chloride, again yields the reddish-violet precipitate. With an ammoniacal silver solution, it forms a yellow precipitate which is exceedingly explosive, exploding even when rubbed in the wet state between the fingers.

Diiododiacetylene CI : C.C : CI is obtained by treating the silver diacetylene compound under water with a solution of iodine in aqueous potassium iodide. It forms colorless crystals and melts at 101° ; it smells like iodoform, and when heated in tubes explodes violently with a flash of red light. If kept for some time exposed to the light it is polymerized, forming a brown, crystalline mass which detonates on heating.

Among other "Intermediate Reduction-Products of the Nitroazo Compounds," J. V. Janovsky and L. Erb (*Berich. Berl. Chem. Gesel.* 18, 1133; 1885) have obtained the trinitroazobenzene by nitrating either mono- or diparanitrazobenzene or azobenzene with fuming nitric acid. It may be crystallized from acetone or alcohol, and is obtained in long sulphur-yellow needles. It melts at 169° to a red fluid, which explodes when heated above its melting-point.

Among the processes used for the production of metallic potassium is that in which an intimate mixture of potassium carbonate and

charcoal is heated in an iron retort. Through the action of the heat a reaction takes place from which carbon monoxide and potassium result. Unfortunately, however, a secondary reaction also occurs, through which a black compound is formed which detonates violently upon the slightest friction. If the potassium be not pure, this compound is readily formed when the metal is exposed to the air, or even when immersed in naphtha.

Liebig was the first to observe (*Ann. Ch. Pharm.* **11**, 182) that metallic potassium united with carbon monoxide. According to Brodie (*Chem. Soc. Qu. J.* **12**, 269; 1859), pure potassium heated to about 80° in carbon monoxide free from air, is at first slowly converted into a dull gray, crystalline substance, $(K_{2n}C_nO_n)$; but if the passage of the gas be continued, a more rapid absorption takes place even at a lower temperature, and the gray crystals are converted into a dark red compound $K_nC_nO_n$. This dark red carbonyl may be preserved under mineral naphtha, but is decomposed with extreme violence by water, and even in the dry state sometimes explodes from causes which have not been made out. When anhydrous alcohol is added to this red compound, it is partly dissolved and partly converted into potassium oxide and potassium rhodizionate. Hence the carbonyl may be regarded as a basic potassium rhodizionate.

The black explosive substance formed in the manufacture of potassium appears to consist of one or both of the compounds just described. According to Kühneman (*Jahresb.* 180; 1864), when potassium is intensely heated in carbon monoxide gas, there are formed, first, a gray mixture of potassium oxide and free carbon, which separates as the apparatus cools from a white to a red heat; and secondly, a dark red body, which separates at a temperature below dull redness, both compounds being formed without access of water or moist air. On collecting these separately, the red substance was found to dissolve in water, forming a solution which exhibited all the reactions for potassium rhodizionate. The gray mass was explosive, and Kühneman attributes this either to the heating of the mass through absorption of water, or to the formation of potassium peroxide (from the protoxide present) and its action on the free carbon.

The name rhodizonic appears to have been applied to two different acids, produced under different circumstances from potassium carbonyl. Berzelius and Wöhler noticed that a red substance is produced by the action of water on the black mass formed in the preparation of potassium by Brunner's process. L. Gmelin found

that the aqueous solution of this substance yields potassium croconate when evaporated in contact with the air, and inferred that it contains an acid different from croconic acid. Heller (*Ann. Ch. Pharm.* **24**, 1; 1837) examined this acid more particularly, and gave it the name of rhodizonic acid. It was further examined by Werner (*J. Pr. Chem.* **13**, 404), but the experiments of these chemists did not determine the composition of the acid. Brodie regarded his acid ($C_{10}H_6O_8$) obtained as above described as identical with that previously obtained by Heller and Werner. On the other hand, Will (*Ann. Ch. Pharm.* **118**, 187; 1861), by the analysis of several salts of the acid, obtained in a similar manner to that of Brodie's, but from the impure potassium carbonyl formed in the preparation of the metal, concluded that its composition is $C_{10}H_8O_{12}$ or $C_5H_4O_6$, and this result is confirmed by Lerch (*Ann. Ch. Pharm.* **124**, 20), who has obtained rhodizonic acid in the free state by decomposing the salts of carboxylic acid, $C_{10}H_4O_{10}$, with acids. The acid obtained by Heller and analyzed by Will and Lerch is styled the α -rhodizonic, and that obtained by Brodie the β -rhodizonic acid.

In the experiments of Lerch, he found that if perfectly unaltered potassium carbonyl, to which Brodie assigns the formula $C_nK_nO_n$, be treated with hydrochloric acid, it yields trihydrocarboxylic acid, $C_{10}H_{10}O_{10}$, which crystallizes in white needles. If the carbonyl be first treated with alcohol and then with hydrochloric acid, it yields black needles of dihydrocarboxylic acid, $C_{10}H_8O_{10}$. If the air has had access to the mass before or after the treatment with alcohol, it afterwards yields, with hydrochloric acid, dark, garnet-red crystals of hydrocarboxylic acid, $C_{10}H_6O_{10}$. Lastly, if the mass has been left in contact with the air till it has turned quite red, and it is then treated with hydrochloric acid, a fourth acid is obtained called carboxylic acid, the potassium salts of which have the formulas $C_{10}HK_3O_{10}$ and $C_{10}K_4O_{10}$. On attempting to isolate this acid, rhodizonic acid is obtained.

Nietzké and Benckiser have repeated Lerch's experiments (*Ber. Berl. Chem. Ges.* **18**, 1833; *July*, 1885), and have proved that his trihydrocarboxylic, dihydrocarboxylic and carboxylic acids are identical with the hexaoxybenzene, tetraoxyquinone and dioxydiquinoylbenzene, respectively, already described by them. The carbonyl-potassium was obtained by passing a current of CO, completely dried and freed from oxygen, over potassium heated to melting in a combustion tube. At the close of the experiment the

potassium had gained in weight about 70 per cent.; confirming Brodie's view that one molecule of CO was absorbed for each atom of K. The product was a solid, grayish mass, with here and there patches of a red-brown, green or black color. After cooling, the tube may be filled with strong alcohol without danger of explosion. On treating the crude product with hydrochloric acid, hexaoxybenzene $C_6(OH)_6$ is produced, which proves that the carbonyl-potassium is most probably $C_6(OK)_6$ or potassium-hexaoxybenzene. The former is accompanied, however, by tetraoxyquinone, its first oxidation product, from which it may perhaps be formed during the solution in HCl, by the reducing action of the K still present upon the corresponding potassium compound directly produced: $(CO)_6 + K_4 = C_6(OK)_4O_2$. To ascertain this, the freshly prepared carbonyl-potassium was dissolved in acetic oxide and precipitated by water. The brown precipitate crystallized from glacial acetic acid gave the characteristic hexacetylhexaoxybenzene. The residue after treating the crude product with alcohol is a dark green powder, which turns red in the air, and which, boiled with HCl, dissolves with a brownish-red color. On cooling, the solution deposits stellate groups of steel-blue needles of tetraoxyquinone $C_6(OH)_4O_2$. If the crude product be washed with dilute alcohol, it turns red, and finally produces an ochre-red powder, the so-called rhodizonic acid. This the authors find to be identical with their dioxydichinoylbenzene $C_6(OH)_2O_4$.

The *Jour. Chem. Soc., Jan.*, 1885, p. 69, contains an account of the further researches* of E. Divers and M. Kawakita of the fulminates, under the title "On the Decomposition of Silver Fulminate by Hydrochloric Acid." The fact has already been noted by them that silver fulminate differs from mercury fulminate in yielding much less than the full amount of hydroxyammonium chloride, and in yielding ammonium chloride. Besides, the silver fulminate is energetically attacked by concentrated HCl. If the heating is not checked, the silver chloride produced is at first stained orange, but rapidly loses its color, imparting it to the acid mother-liquor, and it disappears from this during the subsequent evaporation. In addition, there is at first, among the products of the reaction, an unstable, colorless substance which gives an intense wine-red color with $[Fe_2]Cl_6$, either in the acid or neutral solution. Long standing in the cold, or a few

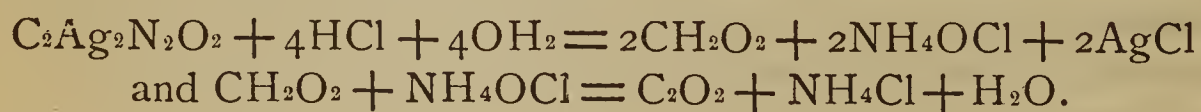
* Proc. U. S. Nav. Inst. **11**, 100; 1885.

minutes' heating, deprives the solution of this power. The only gases liberated by the HCl are CO_2 and HCN. The total nitrogen of the silver fulminate being 9.33 per cent., they obtained

Nitrogen as hydroxyammonium	6.95 per cent.
“ “ ammonia	1.50
“ “ hydrogen cyanide	0.18
“ unaccounted for	0.70
Total	9.33

It is tolerably certain that some ammonia escapes unmeasured. Though Steiner's experiments have been repeated again, using ether in place of water as a menstruum, no oxalic acid was obtained by decomposing mercury fulminate with hydrogen sulphide.

The results show that no difference exists between the silver and mercury salts as fulminates, what difference they show being caused by the metallic radicals. The same hydrolysis occurs with both; but in the case of the silver salt, in consequence probably of the sharp separation of the AgCl in the solid state, the decomposition generates heat so rapidly that the formic acid and hydroxyammonium chloride change into CO_2 and NH_4Cl , thus:



In a paper "On the Constitution of the Fulminates," same journal, p. 77, E. Divers defends the formula $\text{HC}\overline{\text{NON}}\overline{\text{COH}}$, advanced by him,* though he accepts $\text{HC}\overline{\text{NOC}}(\text{NOH})$ as equally satisfactory. Yet an argument in favor of the former is that it shows the hydroxyl in union with nitrogenized carbon, and, therefore, as in cyanic acid, markedly basic, while in the latter the hydroxyl of an hydroxylamine derivative is represented not only as basic, but as capable of taking part without difficulty in double decompositions in water and yielding the various bimetallic fulminates, notwithstanding that the hydroxyl of hydroxylamine has been found analogous to "alcoholic" hydroxyl in carbon compounds, its hydrogen being replaceable by organic radicals only, and not by metals, in presence of water, if at all. Schramm's hydroxylamine compounds, containing Ag or Na, may or

* Proc. U. S. Nav. Inst. **11**, 103; 1885.

may not be metaloxyl-derivatives. The Na compound appears unable to exist in water. The radical :N.O.N: has the support of Goldschmidt, who used it in representing the possible constitution of a dioximido-derivative of phenanthraquinone. Divers dissents from the latter part of Armstrong's theory that, in the conversion of alcohol into fulminate, hydroxyethylaldehydrol is first formed and then acted on half by hydroxylamine and half by nitrous acid, since these two latter bodies cannot act without mutual destruction, or destruction of each other's derivatives.

Armstrong replies to this that it is possible and probable that the latter bodies may exist side by side if a third body is present with which one or both may enter into reaction, or which tends to exercise a protective influence. Divers' own observations on the action of tin on a mixture of HNO_3 and HCl may be cited in support of this view.

Armstrong is inclined to regard $\text{N} \begin{array}{c} \text{C.OH} \\ \diagup \\ \text{C(N.OH)} \end{array}$ or $\begin{array}{c} \text{N.CH} \\ \cdot \\ \cdot \\ \text{O.C(N.OH)} \end{array}$ as

the most probable formulas for fulminic acid, and that they take into account both the elimination of the two nitrogen-atoms as hydroxylamine and also the formation of bimetallic fulminates; but he does not regard them as final. He also points out that, although the fulminates have hitherto been regarded as "dicarbon" derivatives, on account of their formation from ethyl alcohol, there is no direct evidence to support the view; and it is noteworthy that Divers has always failed to obtain oxalic acid by their hydrolysis.

Dingl. Polyt. Jour. **255**, 337; 1885, describes the following novelties in explosives: For the production of gunpowder containing carbon, J. Nordenfelt and F. A. Memling propose to prepare a carbonaceous substance from cotton, woody fibres or similar substances, by treating them in a loose form with hydrochloric-acid gas, whereby the fibre is converted into a brittle substance.* This is thoroughly mixed with the proper amount of a saturated solution of sulphur in carbon bisulphide in a closed vessel provided with a mechanical agitator. The dry mixture of carbon and sulphur is saturated with an aqueous solution of potassium nitrate, and the water evaporated off at a gentle heat. The powder is then finished according to the usual method.

F. W. Gilles proposes to manufacture explosive compounds by

* *Proc. U. S. Nav. Inst.* **8**, 309; 1882.

treating molasses with a mixture of nitric and sulphuric acids. He obtains the explosive in two forms, which he calls solid and liquid nitro-molasses. In both cases 380 grams molasses, 1000 grams fuming nitric acid, and 2000 grams concentrated sulphuric acid, are mixed together. The product, when washed first with cold, then with warm water, deposits a precipitate of a gray-yellow or whitish color, and can be used at once as an explosive material. To obtain the liquid explosive, the nitro-molasses is brought to a composition corresponding to 34 parts carbon, 54 parts oxygen and 12 parts hydrogen, nitrogen and salts. When the molasses contains less oxygen and carbon than the above proportion, it is treated in open vessels with lead peroxide and carbon bisulphide, and the mixture is allowed to ferment at a temperature not exceeding 130° . The prepared molasses is then nitrated. When the molasses contains less oxygen than the proportion stated above, it is treated by oxygen gas forced into it under pressure in closed vessels. The fluid nitro-molasses, when heated, slowly boils at between 180° and 200° , and detonates between 220° and 250° , and can be mixed with any absorbent.

In the same journal, 254, 355; 1884, A. Gacon describes a blasting powder made by mixing 69 parts of potassium or sodium nitrate with 19 parts of sulphur, and adding ash (?) rich in potash or soda to the mixture. It is proposed to obtain this ash by burning dead leaves. 200 grams of tannin dissolved in 8 litres of water are then added to the mixture. One kilo. of this powder is said to blow up 12 to 15 cubic metres of rock. It requires a temperature of 480° for its ignition, and cannot be exploded by concussion, not even when hammered on an anvil. (*Abst. Jour. Chem. Soc., Mar., 1885.*)

In a preliminary note on the "Theory of Explosions" (*Proc. Camb. Phil. Soc.* 5, 309; 1885), R. Threlfall has made an attempt to account for some of the anomalous effects observed in explosions by Sir Frederick Abel. In the well-known experiments with detonators composed of various explosives, Abel was led to imagine that the apparent selective efficiency of chosen substances, when applied to explode one another, might be accounted for on an hypothesis of "synchronous vibrations." It was pointed out that this hypothesis can have no possible physical meaning, unless the vibrations be supposed to take place in the ether; and an explanation was sought in the behavior of the products of explosion as regards their motion in

air and in water. For this purpose, the explosives were treated in groups arranged with respect to their supposed time of decomposition, and it was shown that much would depend on the method of "break-up" of the volume of gas set free by the explosion. The various ways in which the energy of an explosion might be transmitted through fluids were enumerated, and some stress was laid on the effects to be expected if the conditions of explosion were such as to lead to the production of vortex rings.

The necessity of clearly defining the meaning of the phrase "violence of explosion" was pointed out, and it was shown that the "violence," as defined by $\frac{\text{increase of volume}}{\text{time of explosion}}$, would not represent the relative destructive effects of explosions in free air. Various experimental methods of treating the question of "break-up" were described, and further communication was reserved pending the result of experiments still in progress.

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NOTES ON THE LITERATURE OF EXPLOSIVES.*

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The *Trans. Tech. Soc. of the Pacific Coast*, 2, 267 ; 1885, contains a paper by Fred. H. Jenssen on "Dynamite Catastrophes," in which he criticises adversely the theory advanced by L. J. Le Conte† to account for their occurrence. Mr. Le Conte states that 90 per cent. of all the explosions on the Pacific Coast since 1879 occurred during violent desiccating north-wind storms, and that electricity has been the exciting cause in all these cases. Admitting the existence of a dry north wind at the time of the several explosions, it is a fact that the survivors of two of them give reasons for their occurrence which are at variance with Mr. Le Conte's theory.

The explosion at Stege on March 25, 1882, occurred during the manufacture of black powder, called Vulcan B. B. This powder is composed of sodium nitrate, sulphur and charcoal, which are mixed in a perfectly wet state. During this mixing process the superintendent called the foreman and told him that the mixture was not wet enough, and that he should put more water in the basin, as it had been demonstrated by experiment that where the mixture fell below a specified percentage of moisture it would ignite by the friction of the machinery. A few moments after the departure of the superintendent, and before the water was added, the explosion took place.

The explosion at the Giant Powder Works, January 21, 1883, was caused by sparks blown from a wheelbarrow of hot ashes into a box of dynamite.

As to Le Conte's second conclusion—that a dust explosion precedes

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars.

† Proc. Nav. Inst. 12, 181 ; 1886.

that of the dynamite—Jenssen states that in the nitroglycerin department of the dynamite works there is no dust of an inflammable nature; nevertheless a number of explosions have taken place in that department, especially during the first years of the manufacture of dynamite, but now are of rare occurrence. In all the dynamite explosions named, with the single exception of that at the Hercules Powder Works, September 29, 1883, no explosion started in the mixing house, and not one of them can be traced to a dust explosion.

In regard to the danger from lightning, it is admitted that a stroke of lightning will explode dynamite, but small sparks of electricity will not do so. The Swiss committee on the physical qualities of dynamite reported,* some sixteen years ago, that "thunderstorms and lightning involve no special danger to dynamite. As far as conclusions can be drawn from small experiments with heavy discharges of electricity, dynamite, unless well confined, will only burn if struck by lightning. But if well confined, and if the temperature produced by the lightning be high enough, an explosion may possibly take place."

Apropos of the danger of nitroglycerin being exploded by the heat of the sun, the author asserts that *pure* neutralized nitroglycerin or dynamite will stand 170° F. for some time before it decomposes. Long experience has demonstrated that dynamite cartridges in boxes can sustain a temperature of 128° F. for years. But when the dynamite without covering has been exposed for a considerable length of time (varying with the quality) to the sun's rays, on touching it with blue litmus strips the paper turns red.

On January 29, 1881, a man by the name of Lasker was killed in McKean County, Pa., by the explosion of a lot of nitroglycerin which was being thawed by the agent of Roberts & Co. for the purpose of "shooting" an oil well. Suit was brought to recover damages for the loss of Lasker, and the official report of the trial, which was continued from court to court, and which contains considerable expert testimony, is recently come to hand under the title *Roberts vs. Lasker*, in the Supreme Court of Pennsylvania, Eastern District, Paper Book of Plaintiff in Error.

From this we learn that nitroglycerin was used in the liquid state in torpedoes for "shooting" oil wells. The nitroglycerin torpedo consists of a tin shell from three to five inches in diameter, and from five to

* Trauzl Nitrilverbindungen, Wien, 1870.

twenty feet in length, according to the quantity of glycerin which the well-owner desires exploded. All the shells are taken to the wells empty—the longer ones in sections, which are there put together as they are lowered into the well. The nitroglycerin is taken to the wells in square tin cans holding about six quarts each, and weighing when filled about twenty pounds each. This charge does not fill the cans completely, so water is poured in the space above to assist in the preservation of the nitroglycerin. After the tin shell is placed in the top of the well it is filled with nitroglycerin and tightly closed with a cover, in the middle of which is a percussion cap. When thus prepared the torpedo is lowered to the bottom of the well (a distance usually of about 1500 feet) by means of a wire. A perforated iron weight is then strung upon the wire, and, when the torpedo is properly placed, it is exploded by allowing the iron weight to drop from the surface of the ground and fall upon the cap.

The object of "shooting" the well is to remove the dense paraffins or other solids which obstruct the flow of the oil, and to shake the oil sandstone; and nitroglycerin has been found most efficient for this purpose. The right to use this explosive is, however, secured to Roberts & Co. by letters-patent, and has proved a most profitable monopoly, their profits at the time of the trial being fixed at three thousand dollars a day. Naturally their rights were infringed or evaded in many cases, and a class of men known as "moonlighters" sprung up in the oil regions, who exploded torpedoes in the oil wells at night. Others, however, simply placed a large torpedo in the well, and then employed Roberts & Co. to explode a small torpedo above it. The torpedo thus surreptitiously inserted in the well is known as a "setter," and it is believed by those who practise this that they successfully evade the Roberts patent.

As the driving of wells is carried on at all seasons, it frequently happens that the nitroglycerin comes on the ground in a frozen state. That was the state of the nitroglycerin in this case, and it was sought to thaw it by placing the cans (seven of them) in an oil barrel filled with water and passing steam through the water. Four of the cans were placed at the bottom, and the remaining three on top of these. The corks were out of the cans, so that the explosive was surrounded by water. The oil barrel rested on trodden-down snow, and the steam was brought seventy-five feet through a rubber hose stretched over the snow. There were fifty pounds' pressure in the boiler, and the throttle was turned about one-fourth. It seems undetermined

whether there was or was not an iron nozzle to the hose, but the end of the hose reached to within four inches of the bottom of the barrel. The hose remained in the barrel for about one-half hour, when it was taken out, as the water was thought warm enough. After another half hour it was put in again, and had been in but a short time when the agent walked to the barrel and found the water perfectly quiet, and so hot he could but just bear his hand in it (about 115° – 120° F.). He then turned away, and had gone but about fifty feet, and had been away but about twenty seconds, when the explosion occurred. The agent was uninjured, but Lasker, who was in the engine-house, about six feet off, was killed. The defendant sought to show that a "setter" had been put in the well, and that the nitroglycerin for it had been thawed during the night in this same barrel, and that some of the liquid had been spilled in the barrel, but the court refused to admit the testimony. The plaintiff sought to show that the explosion was induced by the agitation set up in the barrel by the escaping steam, or by the energy developed by the steam impinging on the cans, but the real cause was left in doubt.

In the course of his testimony W. B. Roberts stated that he had made nitroglycerin since August, 1866, and that during that time he had made about one million pounds and handled one and a half million pounds. He first became acquainted with it after the explosion in Greenwich street, New York. The remainder of this had been buried by the authorities near Eighty-third street. Dr. Roberts went there, dug it up, and got about one hundred pounds, which he sent to Titusville, and used in the oil wells. The nitroglycerin now used is transported about the country, over the roughest roads, in spring wagons, the boxes being partitioned into squares the size of the cans, and upholstered with leather on the sides and bottom. The empty cans are destroyed by piling them on a brush heap, laying a train of nitroglycerin under it and setting fire to the whole. When explosion takes place at one point it is immediately communicated to the whole. No method of cleansing has yet been found which is effectual.

As giving some idea of the extent of the nitroglycerin industry in this country, we note that Mr. W. N. Hill stated in his testimony that, as chemist to the Repauno Chemical Company, he was, at the time (1882), making from fifty to one hundred thousand pounds of nitroglycerin a month. Sometimes he had made as many as ten runs, of six to seven hundred pounds each, at one time.

In the course of the trial various books were offered in evidence, and the court ruled that they might be read to the court to explain the scientific names and terms used, but not to the jury. The rule seemed to be that books written upon inductive sciences were not admissible, while those on the exact sciences could be offered. He believed the science of chemistry an exact science, and not an inductive one in a philosophical sense of the term, but the scientific knowledge of nitroglycerin might not be so exact as would authorize the reading of authorities in evidence to the jury. Some of these books might be evidence—for example, those which treated of the whole system of chemistry. He had grave doubts as to the articles written in the chemical journals being evidence, but they could be read to the court as law-books.

W. Poetsch (*Dingl. polyt. J.* 255, 216) suggests "Recovering the Waste Acids from Nitroglycerol Works" by the following method: On heating the waste acids, consisting of sulphuric and nitric acids and organic nitro-compounds, at 105°, decomposition of the nitro-compounds ensues, oxidation to carbon dioxide taking place at the expense of the nitric acid which is present. During the reaction enough heat is liberated to volatilize the remaining portion of undecomposed nitric acid and the lower oxides of nitrogen produced, pure sulphuric acid being left in the residue. The author uses a closed vessel of stone or lead, having a perforated bottom 50 cm. above the bottom. The upper space is filled with stones or broken stoneware, and heated by hot air. The waste acid is introduced in a thin stream through a funnel fitted into the cover of the vessel, and, passing over the hot stones, is decomposed. The nitrogenous vapors are led through an earthenware pipe to a cooling worm, and collected in Wolff's bottles, air being introduced to oxidize the gases to nitric acid. The denitrated sulphuric acid flows through the perforated bottom, and is run into receiving tanks. (*Abstr. Jour. Chem. Soc.* May, 1885, p. 619.)

After more than seven years of investigation and experiment, the English royal commission appointed to inquire into accidents in mines has presented its final report, which was issued April 10, 1886, in the form of a blue-book of one hundred and ten pages. The delay is accounted for by the long and difficult quest on which the commissioners were sent. They were to report not only on the causes of

mining accidents, but also on the "possible means of preventing their recurrence, or limiting their disastrous consequences." Not much is recommended in the way of mere legislative changes, but the scientific recommendations are most interesting and important. For example: With reference to the difficult question of the best method of firing shots in mines, they state that "electrical exploding appliances present very important advantages from the point of view of safety over any kind of fuse which has to be ignited by the application of flame to its exposed extremity, as the firing of shots by their means is not only accomplished out of contact with air, but is also under most complete control up to the moment of firing. Their simplicity and certainty of action have been much increased of late years, while their cost has been greatly reduced, and but little instruction is now needed to ensure their efficient employment by persons of average intelligence. The use of electrical arrangements for firing shots in mines, where the employment of powder for blasting is inadmissible, should be encouraged as much as possible."

Again, they state that "it has been shown that mines which have hitherto been considered free from fire-damp may have the air which passes through them vitiated to an extent corresponding to about two per cent. of its volume of marsh gas. The air in many such mines may probably never be entirely free from explosive gas; at all events, in the neighborhood of freshly cut faces of coal and in the return air-ways. It has been demonstrated in our experiments that when the atmosphere contains five to five and one-half per cent. of marsh gas, it becomes highly explosive. We have even obtained explosions which, though less violent, might be, nevertheless, destructive of life if they occurred on the large scale possible in a mine, when the air contained only four per cent. of marsh gas. It will thus be seen that air which would appear free from gas if tested in the ordinary way, may become, by the addition of only about two per cent. of marsh gas, capable of propagating flame and causing destruction, while the addition of about three per cent. converts it into a highly explosive mixture. Air which would appear quite free from gas if examined by a lamp flame, may become explosive when laden with fine, dry coal-dust.* Appliances now exist by which very small proportions of marsh gas in air may be readily detected, and which can be used for examining the atmosphere of a mine. With Liveing's indicator, gas present in the air can be estimated with

* Proc. Nav. Inst. 8, 308 and 459; 1882.

sufficient accuracy for all practical purposes, even when the proportion is as low as one-quarter per cent."

The suggestion, first due to Mr. Galloway, that coal dust alone suspended in air might cause an explosion, is considered, and an account is given of some carefully devised experiments which rather tend to confirm this conclusion. The commissioners discuss with some detail the means of removing this dust, and devote a large section of the report to the question of the conditions under which blasting can be done in safety. Considerable space is devoted to safety lamps, and it is pointed out how great an influence the velocity of the air-currents in the air-passages of a mine has on the safety of a lamp. The commissioners are of the opinion that the older Davy, Clauny, or even Stephenson lamps, have in a great measure lost their value in consequence of the draughts of air from the free ventilation. A current of air of eight hundred feet per minute in an impure atmosphere may, in spite of the wire gauze, effect an explosion in any one of them. The electric lamp is perhaps the chief hope of the miner, though it does not, like the safety lamp, indicate the presence of gas. A rigid daily inspection is recommended. (*Science*, 7, 389, 459; 1886.)

A. Witz (*Compt. Rend.* 100, 1131-1132; 1885) finds that the theoretical temperatures and pressures produced by the explosion of mixtures of coal gas and air, as calculated from the heat of combustion of coal gas, are as follows :

		At constant volume.		At constant pressure.	
		Temp.	Pres.	Temp.	Pres.
1 vol. of gas	+ 6 vols. of air.....	2064°	8.6 atmos.	1596°	6.8 atmos.
1 " "	+ 10 " "	1514°	6.5 " "	1169°	5.3 " "

Any difference between the calculated and observed pressures must be attributed to the action of the walls of the explosion vessel, since Mallard and Chatelier have shown that carbon dioxide and water do not dissociate below 1800° and 2500° respectively in explosions.

Although explosions of coal gas with air are by no means infrequent, the compiler has found considerable difficulty in producing them at will on a laboratory scale by simply mixing air and gas. Acting on these suggestions of the part played by dust, he has placed a small quantity of lycopodium in the stout glass cylinders

used for the experiments. Gas was then allowed to flow in, the vessel covered and shaken. Then on applying a flame there was invariably a smart explosion.

G. Schelgel, in treating of the "Combustion of Hydrocarbons and their Oxides and Chlorides with Mixtures of Chlorine and Oxygen" (*Annalen*, **226**, 133-174), says it has been shown by Bötsch (Abstr. 1882, 456) that in the explosion of a mixture of hydrogen, oxygen and chlorine, water is formed only when the chlorine is present in amount insufficient to unite with the whole of the hydrogen. This result is important, inasmuch as it does not agree with the generally accepted rule that when several substances react simultaneously on one another, those reactions always occur in which the greatest amount of heat is developed. The author has extended these researches to the products of the explosion of mixtures of chlorine and oxygen with gaseous organic compounds. Experiments were made with excess both of chlorine and oxygen, with an excess of oxygen and an amount of chlorine insufficient to unite with all the hydrogen present, and finally with an excess of chlorine, but with an amount of chlorine insufficient to convert the whole of the carbon into carbon dioxide. The organic substances employed were methane, ethane, propane, butane, methyl ether, methyl chloride, ethyl chloride, acetylene and carbon monoxide. No results could be obtained with ethylene, as it unites with chlorine in the dark, and so prevents the formation of a uniform mixture for explosion. The following are the conclusions drawn from these experiments: 1. If a hydrocarbon be mixed with excess of chlorine and excess of oxygen, and the mixture exploded by the spark, the whole of the carbon is converted into carbon dioxide, and all the hydrogen into hydrochloric acid. Hydrogen does not unite with oxygen, nor chlorine with carbon. 2. If excess of oxygen be employed together with an amount of chlorine insufficient to combine with all the hydrogen present, the remainder of the hydrogen unites with the oxygen. 3. If with excess of chlorine the amount of oxygen is insufficient to convert all the carbon into carbon dioxide, there is then also formed carbon monoxide, the proportion of this latter increasing with the deficiency of oxygen. 4. If neither chlorine nor oxygen is present in sufficient quantity for complete combustion, carbon is separated. 5. The organic chlorides and oxides experimented with behaved in like manner to the hydrocarbons. (Abstr. *Jour. Chem Soc.* March, 1885, p. 214.)

F. Bellamy has studied the "Action of Some Metals on Mixtures of Acetylene and Air" (*Compt. Rend.* **100**, 1460-1461; 1885), with the following results: When a spiral of platinum or silver wire, heated just to incipient redness, is brought into a mixture of acetylene and air issuing from a modified Bunsen burner made of glass, the gaseous mixture at once detonates and inflames, but the spiral does not become incandescent. If, however, a copper spiral is treated in the same way, the wire becomes brilliantly incandescent, and eventually ignites the gaseous mixture. A spiral of iron wire behaves in a similar manner, but the incandescence is more difficult to obtain; if the spiral is too hot the gaseous mixture is at once ignited; if too cold, the wire remains non-luminous. Copper or iron wire does not become incandescent in a mixture of air and hydrogen.

Colonel Samuel Wetherill, Jr., has privately communicated to us an account of an explosion of metallic zinc. While engaged in 1854 in the manufacture of this metal, he devised a plan for utilizing the "blue powder," which is the finely divided metallic zinc deposited in the prolongation of the condenser. The process consisted in swedging the powder into blocks and placing these blocks one above another in a furnace, where they melted down and were run into spelter. The workman in charge proposed to facilitate the process by feeding the "powder" directly into the hot furnace and ramming it down with a bar. On trying this the first shovelful exploded, and with such violence that the man was blown from the top of the furnace and the blade of the shovel driven into the roof of the building.

In this connection we may state that with the "blue powder" furnished us from the Bethlehem Works we have easily obtained Schwarz's explosive reaction* with sulphur, though we were unable to get it with the powdered zinc of commerce, owing probably to its being superficially corroded.

We are indebted to Sir Frederick Abel for a copy of his address on "Accidental Explosions Produced by Non-Explosive Liquids," which was delivered before the Royal Institution of Great Britain, March 13, 1883, and which deals with the explosions produced by the petroleum oils. The lecturer cites numerous instances of explosions from this cause which have occurred both on land and at sea,

* *Proc. Nav. Inst.* **9**, 750; 1883.

details the attending circumstances and seeks to explain the cause. The most interesting to us are those on the Coquimbo, Cockatrice, Triumph and Doterel, which the lecturer now believes to have been caused by the petroleum spirits used in the xerotine siccative.*

In the *Proc. Am. Asso. Ad. Science*, 33, 130; 1885, Charles E. Munroe proposes to use an electric motor and gun-cotton for illustrating experimentally the "Conversion of Mechanical Energy into Heat." For this purpose a Griscom electric motor is clamped to the base of a retort stand with its axis of revolution vertical, while a brass disk to which a flat cork is cemented is clamped on the end of the shaft. A shallow cavity is made in the cork, the bottom of a test tube is placed in the cavity, and the tube clamped in place. Gun-cotton is now rammed into the tube, the vessel corked, and the motor set in motion. With four Grove cells the friction of the cork on the tube generates sufficient heat, in half a minute, to fire the gun-cotton and blow the cork from the tube. With this apparatus the difference in the points of ignition of gun-cotton and gunpowder, and of gunpowder grains of different sizes and densities, besides many other experiments depending upon the generation of heat through friction, may be easily and simply shown.

In the study of the "Action of Primary Alcoholic Iodides on Silver Fulminate," by G. Calmels (*Compt. Rend.* 99, 794-797), 25 grams of dried silver fulminate were heated with 25 grams of methyl iodide and 40 grams of ether in a sealed tube at 50° for twenty-four hours. The products were silver iodide, methyl carbylamine and β -nitroethylene. Ethyl iodide and the higher primary iodoparaffins react in a precisely similar manner.



In this reaction silver fulminate is split up into two parts. In order, if possible, to obtain the intermediate compounds, $\text{CNMe} : \text{CMeNO}_2$, $\text{CNEt} : \text{CEtNO}_2$, 100 grams of methyl iodide mixed with 50 grams of ether were allowed to act on 50 grams of the dried fulminate at the ordinary temperature for four or five days, but the only products obtained were α -nitroethylene and methylcarbylamine. Ethyl iodide and its higher homologues behave in the same way.

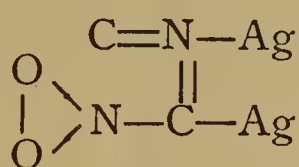
The nitro-derivatives of the ethylene series are characterized by their power of existing in two modifications, the α -derivatives forming

* *Proc. Nav. Inst.* 8, 313 and 459, and 671; 1882.

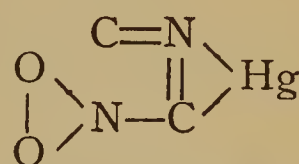
colorless liquids soluble in ether and chloroform, whilst the β -derivatives are yellow, resinous solids insoluble in the same solvents. From their chemical behavior, it would seem that the former are the true nitro-derivatives, whilst the latter are oximido-derivatives.

From these results it follows that silver fulminate contains two dissymmetrical groups, each of which contains one atom of silver. One of these groups is silver cyanide, CNAg , whilst the other contains the

sub-group $\text{N} \begin{array}{c} \diagup \text{O} \\ | \\ \diagdown \text{O} \end{array}$ and the second atom of silver, the latter being united with the second atom of carbon, which is in direct union with the nitrogen in the first group (this nitrogen acting as a pentad), and thus links the two groups together.



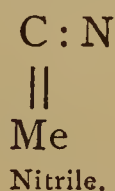
Silver fulminate.



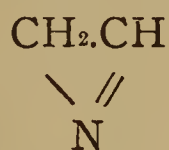
Mercuric fulminate.

It is evident from this formula that the two metallic atoms in the silver fulminate have different functions, and this explains the non-existence of mixed fulminates of the alkali metals. The formula also explains generally the observed action of the halogens on the fulminates.

The fulminates are isocyanides or metallic carbylamines united by nitrogen to a bivalent residue of a metallic derivative of nitromethane, the metal attached to the nitro-group being any metal whatever. This function, which is peculiar to the carbylamines and does not appertain to the metallic nitriles (cyanides), may be termed the carbazilic function. The relation of the carbazilic type to the allied types is shown by the following formulas:—



Nitrile.



Metanitrite.



Carbylamine.



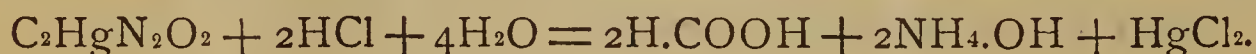
Carbazilic.

In the study of "Mercury Fulminate," L. Scholvien finds (*J. pr. Chem.* 30, 91-92; 1885) that a solution containing sodium fulminate is formed by treating mercury fulminate suspended in water with sodium amalgam. When this solution is decomposed with dilute sulphuric acid, and shaken up with ether, the ethereal solution is found to contain two acids of the composition HCNO . The less

soluble of these crystallizes from ether in colorless needles, melting at 85° ; it is soluble in lukewarm water, but is decomposed by boiling water. It forms a red, insoluble silver salt, a dark yellow mercuric salt, and light yellow lead salt; its solutions yield a deep red coloration with ferric chloride. Decomposed by hydrochloric acid it yields hydroxylamine. The more soluble isomeride may be crystallized from hot water, yields no coloration with ferric chloride, and forms no insoluble metallic salts. The aqueous solution of sodium fulminate gives a precipitate of silver fulminate with silver nitrate, which when treated with metallic chlorides and aniline hydrochloride forms double salts. It is decomposed by ethyl iodide, and with potassium sulphide yields an easily explosive compound.

Mercury fulminate and thiocarbamide yield carbon monoxide, mercuric sulphide, carbamide, a compound thiocarbamide and mercuric thiocynate.

A. Ehrenberg states (*Jour. prak. Chem.* 30, 38-68; 1884) that Carstanjen and he have shown (*Abstr. Jour. Chem. Soc.* 816, 1882) that when mercury fulminate is decomposed with aqueous hydrochloric acid it yields its nitrogen as hydroxylamine hydrochloride. A further examination of this reaction has proved that both carbon monoxide and carbon dioxide are formed. The quantity of these compounds produced is but small, more especially when the decomposition is effected in the absence of air; and it appears that they owe their origin to the decomposition of formic acid, which the author has shown is produced by the action of aqueous hydrochloric acid on mercury fulminate. The reaction taking place may be represented as follows:



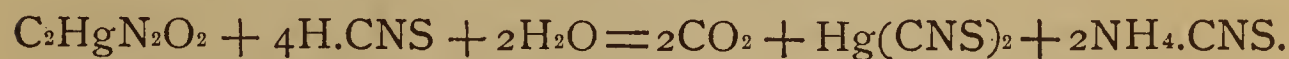
In the hope of realizing the following decomposition, and thus obtaining fulminic acid, $\text{C}_2\text{HgN}_2\text{O}_2 + 2\text{HCl} = \text{HgCl}_2 + \text{C}_2\text{H}_2\text{N}_2\text{O}_2$, the author passed dry hydrochloric gas into perfectly dry ether containing mercury fulminate in suspension. Mercuric chloride is produced, and the ether holds in solution a compound which undergoes spontaneous decomposition, most probably fulminic acid. If this ethereal solution is carefully added to aqueous ammonia, and the ethereal solution separated from the aqueous solution, the latter contains a yellow solid, which is sparingly soluble in cold water, but soluble in hot water, from which it may be obtained in yellowish

needles. The analysis of this compound shows it to be $C_3H_4N_4O_2$. It forms with silver nitrate a compound $(C_3H_4N_4O_2), AgNO_3$, insoluble in cold water, and with an ammoniacal solution of copper oxide the compound $(C_3H_4N_4O_2)_2CuO(NH_3)_2$, which is obtained as a light-blue granular precipitate. From the ammoniacal solution from which the above compound was obtained the author has isolated an acid isomeric with fulminic acid, to which the name *isofulminuric acid* is given. It is easily soluble in water, from which it separates in ill-defined crystals; absolute alcohol dissolves it easily, and by cooling the hot saturated solution it is obtained as a white powder. With silver nitrate its aqueous solution gives a white amorphous precipitate of $C_3H_2N_3O_3Ag$, but yields no precipitate with ammoniacal solutions of copper oxide, lead acetate or mercuric chloride. The silver, ammonium and barium salts of this acid are described.

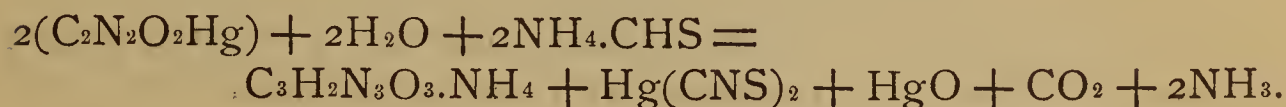
Together with this acid there is formed a small quantity of a compound more easily soluble in ether than isofulminuric acid, which is most probably the ammonium salt of amido-fulminuric acid, $C_3H(NH_2)N_3O_3.NH_4$.

Its aqueous solution gives precipitates with silver nitrate, lead acetate and copper sulphate, and a blood-red to brownish-red coloration with ferric chloride.

Thiocyanic acid reacts with mercury fulminate in a manner analogous to aqueous hydrochloric acid; mercuric thiocyanate, ammonium thiocyanate and carbon dioxide are produced, the production of the ammonium salts arising from the instability of hydroxylamine thiocyanate. The reaction may be represented thus:



The action of ammonium thiocyanate on mercury fulminate is analogous to the action of the chlorides of the alkali metals, but is more energetic; it may be expressed as follows:



A. Ehrenberg (*J. pr. Chem.* [2], 82, 230-234) obtains "Sodium Fulminate," $C_2N_2O_2Na_2 + 2H_2O$, by the action of sodium amalgam on an aqueous solution of mercury fulminate, the solution obtained being evaporated over lime and sulphuric acid. It crystallizes in colorless, lustrous prisms, which explode with great violence when rubbed; when left for some time over sulphuric acid and lime the

crystals become white and opaque, the anhydrous salt being formed. If the aqueous solution is evaporated on the water-bath, it turns yellow, and finally brownish-red. Similar changes occur on exposure to air. When an aqueous solution is electrolyzed, the products are ammonium carbonate and cyanate, a brown, humus-like substance, carbon monoxide, nitrogen and nitrogen monoxide, and towards the end of the decomposition carbon dioxide and small quantities of hydrogen cyanide. Hydrogen peroxide converts it into ammonia, sodium carbonate, carbon dioxide and hydrogen cyanide.

The *double salt* $C_2N_2O_2Na_2C_2N_2O_2Hg + 4H_2O$ is obtained by the action on mercury fulminate of half the amount of sodium amalgam necessary for its complete decomposition, or by mixing solutions of the two component salts. It crystallizes in colorless plates, is readily soluble in water, and is less explosive than the mercury salt. When a small quantity of dilute acid is added to an aqueous solution, mercury fulminate is precipitated. Strong hydrochloric acid decomposes it; mercury, sodium and ammonium chlorides, and hydroxylamine hydrochloride being obtained. (*Abstr. Jour. Chem. Soc.* 1191, Dec., 1885.)

T. Sandmeyer (*Berich. Berl. Chem. Ges.* **II**, 1767; 1885) finds that "Ethyl Hypochlorite" is formed when gaseous hypochlorous oxide is passed into alcohol, or when concentrated aqueous hypochlorous acid is mixed with alcohol. The most convenient method of preparation is to pass chlorine into an ice-cold solution of soda as long as it is absorbed, and immediately add, with agitation, one-tenth the volume of alcohol. The ether very soon separates, and after washing and drying with calcium chloride may be distilled. *Ethyl hypochlorite*, $ClOEt$, is a yellow, mobile, and very volatile liquid. It distils at 36° (under 752 mm. pressure undecomposed), but if the vapor be superheated a violent explosion occurs. Powdered copper (precipitated from copper sulphate with zinc), when added to the cold liquid, causes a similar violent explosion. Carbon and sulphur do not act upon the liquid. Ether, benzene and chloroform do not act rapidly on this ethereal salt, but its solutions in them appear to decompose gradually. When exposed to the direct rays of the sun it explodes violently, even when the vessel containing it is surrounded by iced water. In diffused daylight decomposition takes place more slowly, but the liquid becomes gradually warm, and after a time boils

violently, and leaves only a little acid liquid smelling of ethyl acetate. In its general properties it resembles hypochlorous oxide very closely, and acts on ammonia and many organic substances as a strong chlorinating and oxidizing agent. It immediately decomposes hydrobromic and hydriodic acids, liberating the halogens.

In the study of the "Nitro-Derivatives of Ethylene" A. Villiers (*Bull. Soc. Chim.* 48, 422-424) obtained the compound $C_2K_2(NO_2)_4$ by the reduction of the potassium-derivative of tetranitroethylene bromide (Abstr., 1884, 33). This body undergoes decomposition after several days, forming a purplish-brown amorphous mass; potassium-hydrogen carbonate is also formed, and small quantities of an unstable substance soluble in water with an intense red color. By treating the compound $C_2K_2(NO_2)_4$ with chlorine, bromine or iodine in the presence of potash, tetranitroethylene chloride, bromide or iodide is formed. The aqueous solution of the potassium compound of tetranitroethylene bromide is slowly dissociated, an oily, colorless liquid being formed, which appears to be tetranitroethylene bromide. The *silver* compound $C_2(NO_2)_4Br_2Ag_2O$ crystallizes in brilliant yellow needles; it detonates at about 100° , and at 40° it is exploded on the slightest friction, although it cannot be exploded by friction at the ordinary temperature. It is blackened by the action of light. The *potassium* compound of tetranitroethylene chloride $C_2(NO_2)_4Cl_2KHO$ forms pale yellow crystals; it detonates at 147° . The corresponding iodine compound crystallizes in yellow plates, which alter rapidly and become black; it explodes at a higher temperature than the chlorine and bromine compounds, but causes a much more violent explosion. In the preparation of tetranitroethylene bromide (Abstr. 1882, 815) the flask is cooled by immersing it in cold water directly the action tends to become at all violent, and the operation is then conducted as usual; the formation of nitrous gas is almost entirely avoided, and much smaller quantities of other ethylene compounds are formed. The further reduction of tetranitroethylene bromide results in its complete decomposition into ammonia, and hydrogen cyanide and bromide. A small quantity of an alkaline compound was, however, obtained by treatment with ammonium sulphide; it contained potassium and sulphur, and formed a beautiful orange platinochloride. (Abstr. *Jour. Chem. Soc.* 1044, Oct., 1885.)

The following "Nitro-Derivatives of Furfurane" were studied by P. Prieb (Ber. 18, 1362; 1885). *Nitroethenyl furfurane*,

$C_4H_3O.C_2H_2.NO_2$, is readily obtained by acting on furfuraldehyde in an alkaline solution with nitromethane. By treating this compound with nitric acid, *nitroethenyl-nitro-furfurane*, $NO_2.C_4H_2O.C_2H_2.NO_2$, is formed. When this is oxidized with chromic mixture it yields *nitro-pyromucic acid*, $NO_2.C_4H_2O.COOH$. This forms an insoluble silver salt which explodes on heating.

In referring to the statement that "Franklin,* in his Letters on Electricity (June 29, 1751), was the first to suggest the employment of frictional electricity for ignition of gunpowder," it may be interesting to note the following item from the *Maryland Gazette*, Annapolis, Md., June 14, 1749: "On Friday last (June 9), the gentleman who has exhibited the electrical experiments in town removed his machine off to the south side of our creek [Spa Creek?], and having set some spirits of wine in a small vessel on a table on the north side, he caused a spark of electrical fire to dart across in an instant through 200 yards of water, which set the spirits in a blaze the first attempt and several times afterwards, and discharged a battery of eleven guns, to the surprise and great satisfaction of the spectators." The name of the exhibitor is not given, although an advertisement of his exhibition, together with a detailed list of his experiments, is repeated in several of the previous numbers.

* Proc. Nav. Inst., 11, 773; 1885.

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NOVEMBER, 1886.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

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No. XII.

In the *Phil. Mag.* **21**, 164-180; March, 1866, R. Threlfall published at length the results of his investigations "On the Theory of Explosions." † In his papers on the action of detonators, Sir Frederick Abel ‡ described some curious experiments, which he strove to account for by an hypothesis of "synchronous vibrations." § This hypothesis has been treated of at length by Berthelot, || and although much light, both experimental and theoretical, has been thrown on the matter by Vieille and Berthelot, the explanations offered by the latter do not seem altogether satisfactory to Mr. Threlfall, and he has concluded that something of interest might be gathered from a study of the behavior of the products of explosion, especially as regards the manner in which they escape from the centre at which the explosion takes place. Much might be learned from a measurement of the velocity of transmission of a shock to points at small distances from the centre of explosion. This would be merely a question of apparatus, and Lord Rayleigh suggested the use of a sensitive flame and revolving mirror, which would, at all events, give some idea of the sort of disturbance experienced; but Threlfall deemed it best to

* As it is proposed to continue these "Notes" from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars.

† Proc. Nav. Inst. **12**, 197; 1886.

‡ Phil. Trans. **159**, 489; 1869.

§ Proc. Nav. Inst. **4**, 31; 1877.

|| Proc. Nav. Inst. **10**, 206; 1884.

begin by examining cases where the results of explosion could be seen and watched.

For this purpose he constructed a tank measuring a yard each way, and provided with windows in the sides. The tank was filled with water, and water-tight glass bulbs of $\frac{1}{2}$ inch diameter, filled with mercuric fulminate, were sunk to a depth of 18 inches in the water, fired by electricity, and the course of the *débris* from the explosion noted. As the torpedo was suspended vertically, this *débris* had the appearance of being shot down to the bottom of the tank—not in a jet, as might have been expected, but with exactly the rolling motion that smoke has in coming out of a chimney—as if, in fact, there was vortex motion of some sort. The constancy of the downward action of the explosion suggested that it was due to the want of symmetry introduced by the neck and wires of the torpedo. Hence experiments were made in which the torpedoes were placed horizontally, and then the *débris* seemed to move, with its peculiar rolling motion, horizontally away from the neck. In fact, the appearance presented to the unaided eye was that of a more or less definite column of rolling white smoke shot out with great velocity, and coming to rest very rapidly when about five inches from the centre, as if acted upon by an irresistible force. Experiments were also made by exploding a charge in the centre of a Florence oil-flask filled with red dye and immersed in the water. The dye was shot out with the *débris*, and the flash appeared to be suddenly stopped some two or three inches outside where the flask would have been if it had not disappeared. There were, however, so many sources of misinterpretation to be feared in this method of observation that it was not continued, but the experimenter contented himself with noting the peculiar rolling and the dead-beat motion of the dye as it was shot out.

Experiments were now made to determine if the directions of projection of the *débris* coincided with the directions of propagation of the streams of explosive energy. For this purpose two forms of gauges were devised. The first consisted of a short, stout brass cylinder, closed at one end with a brass cap, and at the other by a diaphragm of thin sheet-rubber. To a hole in the side of the cylinder a smaller brass tube was fitted, and this was attached to a glass tube. The apparatus was then filled with colored water, and, of course, when held vertically, any pressure on the rubber caused the water in the gauge to rise in the tube. Two such gauges were made, and then were firmly fastened to the two adjacent sides of the tank,

the centres of the rubber faces being as nearly as possible in the same planes with the torpedo. Explosion caused these gauges to register, but they were not uniform in action, and were difficult to read, so they were abandoned for a gauge in which a piston moved in the horizontal brass cylinder, and the piston-rod abutted on the bob of a lever pendulum. To the other end of the pendulum a long, light index was attached. By firing some dozen torpedoes arranged as symmetrically as possible, he found that the indications of the latter gauges were nearly proportional. Explosions were then produced in torpedoes purposely made unsymmetrical, either by having the glass too thick on one side, or by turning up the ends of the covered conducting wires so that they entered the bulb horizontally and facing one of the gauges. The effects now became more puzzling, but on the whole there can be no question that the gauge towards which the bulb was turned suffered most. In fact, the direction taken by the streams of explosive energy appeared to coincide with the directions of projection of *débris*, and with the direction foretold from the initial conditions.

The experiments were repeated at various distances and in various manners with more or less compressed charges, and with variations in the position of the firing-point. The pendulum readings were on the whole certainly proportional to the direction of explosion as foretold from the initial conditions. Of course in some few cases there were unexpected actions on the gauges ; but this was hardly avoidable, since the previous experiments had shown how small a change in initial conditions could lead to great variations in the result. The position of the firing-point was the least satisfactory part of the experiments ; most of the failures could be traced to imperfect centring of the firing-point ; about ten per cent. of the experiments failed to travel on the paths laid out for them. These experiments leave little doubt that the direction in which the maximum explosive effect is transmitted will in a great measure depend on the initial arrangement of surrounding obstacles ;* at all events, when the explosion is caused by fulminate of mercury and small charges are used.

The shock of an explosion must be transmitted in one or more of three different ways :

I. By actual bodily motion of the products of explosion through the surrounding medium, either alone or becoming more and more mixed up with the medium itself, which is thereby set in motion.

* Proc. Nav. Inst. 9, 735 ; 1883.

II. By an undulatory motion set up in the medium.

III. By vortex-ring motion.

In the explosion of gunpowder and other slow explosives the energy is transmitted chiefly by I and II. The distance to which a considerable quantity of the energy may be conveyed by means of waves of comparatively great amplitude is in some cases remarkably great. This is evidenced by the effects produced by the explosion of powder magazines.

In the case of the fulminates of mercury and silver, gun-cotton and nitroglycerine—that is, explosives of the class examined under water—the effect falls off very rapidly with the distance, and in water, at all events, is of a directed character. This would point to the third mode of transmission being in these cases of some importance; and if we consider the way in which the products of explosion escape, we shall find that the conditions for the production of vortex motion do in fact exist. Let there be a sphere of fulminate of mercury fired from its geometrical centre. Then, by Vieille's* experiments on the time of explosion, it seems likely that the outer portions of fulminate will be decomposed before they are removed to any appreciable distance from their original positions. We shall therefore have a sudden expansion in all directions, caused by the increase in volume of the explosive substance during the explosion. There seems no reason, under perfectly symmetrical conditions, why the expansion should not go on as it began until the cooling of the sphere of hot gases becomes so marked as to prevent further expansion.

If the conditions, however, are not such as to allow of symmetrical expansion—as always occurs in practice—then we shall have the bounding surface of the explosion gases more curved in some places than in others; that is, the strain will be greater at some parts than at others, and in fact may become so great at points of great curvature as to lead to a state of “breakdown.” In other words, the compressed gases will in this case escape, not by gradual expansion, but by jets, from points whose position is fixed by the conditions of explosion. In these jets we should have the necessary and sufficient conditions for the establishment of vortex motion. If vortex motion were set up, then it seems likely that much greater effects might be transmitted in some directions than in others, though at considerable distances the effects would tend to become uniform in all directions. The author believes that this view of the actions of explosions will enable

* Compt. Rend. 1882 and 1883.

us to explain several difficulties occurring in the interpretation of Abel's experiments. Among these are: The want of correspondence between the explosive actions, as measured by the effect produced on copper plates, and the effects produced in causing other explosions; the apparent capriciousness of explosions of the more violent kinds; the production of explosions by influence.

In his discussion of explosions, Berthelot has not added anything to the generally accepted theory that the explosion of gunpowder differs in no way from ordinary combustion, except that it is more rapid. His theory of detonation, however, is novel, and it may be summed up as follows: The kinetic energy of the shock of the explosion (by the detonator) is transformed into heat at the point struck; the temperature of this point is thus raised to the temperature of explosion; a new shock is produced which raises the temperature of the neighboring portions to the same degree; they then explode, and the action is thus propagated with an ever-increasing velocity.

Many experiments tend to show the justness of this view. To begin with, Abel found that almost any variety of effect could be obtained by burning explosives under diminished pressure. For, the lower the pressure, the more easily do the products of decomposition escape and carry with them the energy due to their liberation. By this means the temperature of explosion is constantly kept down, and the chemical character of the products modified in such a way that they correspond to the temperature. In other words, the compounds liberated are, as a rule, more complex than those which would be set free at a higher temperature, and therefore the energy run down is less.

Again, it will come to the same thing, so far as the propagation of an explosion is concerned, whether the products of decomposition are facilitated in their escape by conducting the experiment in a partial vacuum, or whether the decomposition is itself so slow that the products are enabled to escape without marked hindrance under ordinary pressure. Now, the resistance of the air to the escape of the products of combustion will depend on the rate at which they are liberated. And the shock given to neighboring portions of the explosive will be proportional to the pressure of the explosion gases at these points, and therefore ultimately to the resistance of the air, and hence to some function of the velocity of decomposition. But, in order to convert an explosion by combustion into an explosion by detonation, what is required is that the temperature of any point shall be raised

sufficiently to determine its complete, as distinguished from its incomplete, decomposition. The raising of the temperature of any point, however, will depend on the violence of the shock to which it is subjected ; and this, as before stated, will be proportional to some function of the velocity of the decomposition producing it. If the necessary temperature is anywhere attained, we shall have detonation thereafter ; if not, an explosion by combustion will result. It appears, therefore, that in order to produce a detonation, we require the initial velocity of decomposition to rise above a certain minimum value—that there is, in fact, a “critical velocity” of initial decomposition determining the kind of reaction which ultimately takes place. If the temperature of the whole mass be previously raised, then the critical velocity will become less. Berthelot considers that a specific change takes place in the stability of an explosive as its temperature is raised. This is doubtless true ; but if a minimum temperature of any part be the necessary and sufficient condition for the production of a detonation, then the ease with which it can be obtained, when the mass starts with a high temperature, will, *cæteris paribus*, be greater than if the original temperature is low. If, therefore, we find that nitroglycerine is more liable to detonation the higher its initial temperature, we shall not be required to make any assumption as to “increased sensitiveness,” since we see that the minimum temperature will be more easily reached, and that therefore the critical velocity of initial decomposition may be smaller. In other words, supposing we try to detonate nitroglycerine by an explosive which just fails at ordinary temperatures, we should expect its chances of success to increase as the temperature rises ; and this does, in fact, occur.

The sensitiveness of an explosive to detonation has been found to depend on its state of aggregation. The critical velocity required to produce detonation will, *cæteris paribus*, depend on the nature and value of the elastic constants of the explosive, as well as of the medium in which it is to be exploded. We should, in fact, expect a change in the critical velocity of detonation if we exchanged the viscous resistance of liquid nitroglycerine for the elastic resistance of the same substance when frozen. Again, it seems possible, as a result of this theory, that less powerful detonation might be required to explode a given substance in water than in air ; but the author is not aware of any experiments on this point. And so in other cases, though the critical velocity of detonation must necessarily be a very

complex function, and difficult to predict; yet there appears to be no reason on that account to minimize its importance. On the other hand, it seems to the author to be in complete harmony with Abel's experiments, and substantially embodies the views set forth by Dixon,* and the author knows of not a single experiment which offers any evidence against it. What is required by the theory for the production of a detonation is that a small part of the mass should be raised above a given temperature, and not that a large portion should be raised to a temperature below it.

This leads at once to the consideration of the second point—viz.: the action of detonators. The apparently anomalous effects discovered by Abel may be summed up by taking the most extreme case. Gun-cotton could be detonated by a charge of fulminate of mercury, whereas ten times as much nitroglycerine was required to cause a similar sample of gun-cotton to detonate. By firing the detonating charges on copper plates, Abel naturally observed that the destruction produced by the nitroglycerine was much the greater, and hence concluded that some other factor besides the "explosive violence" must come into play. This is undoubtedly true, but the mistake arises in looking at the experiments from one point of view alone—viz.: that of the copper plate. There will be no effect produced on the plate at all till the resistance of the air becomes greater than that of the plate; and this will never be the case, however great the volume of gas liberated, unless the time of explosion be sufficiently short. The resistance of the air varies at least as the square of the velocity of attack, and therefore this will be the conditioning factor of the destructive effect producible by explosions in free air. For a given increment of volume occurring in an explosion, till the time of explosion diminishes to a certain value depending on the strength of the plate, no effect will be observed; directly this limit is passed, the destructive effects will depend in the usual manner on the quantity of energy liberated. There is, in fact, a critical velocity of explosion below which the plate will not be attacked. But in a detonation the case is different. We do not require any great destructive effects: we only require that the time should be so short that a portion, no matter how small, of the substance to be detonated should be raised to the appropriate temperature. If the detonator has a time of explosion too great, then, although the air may be the stronger obstacle and the explosive destroyed, no detonation will be

* On Conditions of Chemical Change in Gases, *Phil. Trans.* 1884.

produced. This is precisely what happened in Abel's experiments, when the gun-cotton was blown to pieces by the nitroglycerine. The instantaneous rise of pressure is not so great for nitroglycerine as for fulminate of mercury, though the energy run down is much greater. This point has been satisfactorily proved by Vieille in his experiments with the crusher gauge. Moreover, the density of mercury fulminate is three times that of nitroglycerine, which allows a given mass to be on the whole much nearer its work if it consist of fulminate of mercury, than if it consist of nitroglycerine.

We ought not therefore to be surprised that the detonation of gun-cotton is easily accomplished by fulminate of mercury, and hardly accomplished by nitroglycerine. If there is any surprise, it would seem more fitting that it should be exhibited at the detonation which large charges of nitroglycerine seem able to effect.

This fact would tend to show merely that nitroglycerine has a velocity very near the critical point for gun-cotton—so much so, that when large charges are employed the acceleration in the explosion of the nitroglycerine is sufficient to pass the limit. We know from Dixon's work on gases that at first the explosion gains in velocity till the steady velocity of detonation is obtained, and there seems no reason against, but, on the other hand, every probability in favor of, the same thing taking place in nitroglycerine.

Above and beyond this, the difference in the mode of application of the two detonators must be taken into account. In Abel's experiment the fulminate was enclosed in a tube of copper or tin plate, while the nitroglycerine was merely applied in a capsule whose diameter was large compared with its depth. The upper end of the fulminate tube was probably closed by the electric firing-apparatus; and this, as was shown by the experiments in water already described, together with the fact that the fulminate was fired at the top, would give it an enormous advantage. For there is considerable probability that in explosions of high velocity in air, the final mode of "breakdown" of the gas liberated is very dependent on the initial conditions, just as it is shown to be in water. The nitroglycerine was deprived by Abel of these advantages; and for these and the reasons above mentioned, though it was able to blow blocks of compressed gun-cotton into powder, and even to cause some of this powder to penetrate the hard wood of the support, it failed to cause detonation.

The other apparently anomalous facts observed by Abel require further treatment, and most of all those explosions by influence, which

seem at first sight only explicable by some theory such as that of synchronous vibrations, suggested by Abel himself. The difference in the behavior of nitroglycerine and fulminate of mercury, regarded as detonators, led Abel to suggest that there might be some synchronism between the vibrations caused in air or ether by the latter explosive, and the natural period of vibration of a gun-cotton molecule. At all events, the supposition is made that fulminate of mercury when exploded can produce vibrations which are not produced by explosions of nitroglycerine, and that the superior detonating power of fulminate of mercury may be due to the presence of these vibrations. The first set of experiments bearing on this point have been already discussed, with the result that the hypothesis is perhaps unnecessary. There are, however, a great number of other experiments, some of which cannot be so easily explained. In one case an explosion was induced in a charge of fulminate of silver placed at the end of a tube by the explosion of a similar charge at the other end. The effect was not interfered with by placing diaphragms across the tube; but the state of the internal surface of the tube seemed to exercise considerable influence. Experiments were also made on the action of fulminate of mercury on gun-cotton* through tubes. The great influence exerted on the detonating power by the smoothness or roughness of the walls of the tube seems a strong argument against the supposed synchronism having much to do with the effect in these cases. On the other hand, it is just what we should expect if there was bodily motion down the tube, or even if, as in the case where diaphragms were inserted, the motion was transmitted from layer to layer without any great amount of displacement in each individual particle. It seems possible that some vortex motion caused by the "breakdown" might be transmitted through the tube, and that the diaphragms merely served to change the portions of air of which the rings were actually composed. The author admits that this is not very satisfactory; but if the roughening of the internal surface of the tubes actually exerted the effect attributed to it, we are justified, in the author's opinion, in supposing that the explosions were not caused by the transmission of vibrations through the material of the pipe itself. Again, vibrations, to be of any effect in producing chemical change, must be comparable as to period with the molecular vibrations. If such vibrations are transmitted through ether, it is difficult to see where

* Proc. Roy. Soc. 22, 160; 1874.

the influence of chalking the inside of the tubes can come in; and if through air, their wave-length would be too small (as will be shown) to be likely to be much influenced by particles of the size of chalk-dust.

The similar experiments of Champion and Pellet* are sufficiently explained by their statement that they used iodide of nitrogen. Unless any one likes to suppose that the period of a fiddle-string may be comparable with the period of an iodide-of-nitrogen molecule, the further experiments of Champion and Pellet cannot be held to have much bearing on the subject. One can only wonder that they found a string that would vibrate slowly enough not to fire their iodide. As to their experiments with mirrors, blackened or otherwise, the results obtained might be anticipated on almost any theory except that of "synchronous vibrations." For the vibrations supposed on this theory to be most active would be precisely those absorbable by lampblack. This point has been investigated by Berthelot in a manner which leaves little doubt that he misunderstood Abel's theory. In order to show the importance of vibrations in producing chemical change, Berthelot experimented on various chemicals by swinging them on tuning-forks. No effect was produced, nor indeed was it to be expected, unless the reagents were of such a nature that they required intense shaking to keep them mixed. Berthelot also experimented on ozone at much higher frequencies of vibration by causing a tube filled with the gas, mixed with oxygen, to be set into violent longitudinal vibration. No change in the ordinary rate of decomposition of ozone was observed. This is very interesting, but does not seem to touch Abel's theory. In order to disprove the theory, Berthelot ought to have made his tube vibrate till it got luminous, and observed the effect on the ozone all the way up.

There are many well-established cases of torpedoes exploding one another by influence, and the same thing occurs in firing dynamite shots in mines. The former alone possesses any interest for our present purpose. If the effects due to fulminate of mercury when fired under water are in any way similar to those which may be supposed to take place on the detonation of large charges of gun-cotton, then, by the experiments described above, it would be likely that quite extraordinary effects might be propagated in some cases. There ought, however, to be a capriciousness in the observed action of torpedoes on one another; whether this has been observed or not, the author is

* Compt. Rend. 75, 110.

unable to state, but he assumes that it has not, and that here we have a case where the effect is largely due to "synchronous vibration." He therefore considers the ways in which vibrations of sufficiently small period could be transmitted, first assuming that no vibrations can have any influence unless they are of such period as to be comparable with the natural period of vibration of the molecules of the substance to be exploded.

Let a body be gradually heated, and its temperature measured as soon as light comes from it having the same refrangibility as the line *A* in the solar spectrum. Let the temperature be, say, of the order of 1500° C. Then the molecules of the body will be vibrating in some way comparable with the period of the *A* line; that is, about 4×10^{14} times per second. Suppose gun-cotton could be heated red hot without decomposition; then its molecular period would be of this order. We are quite unable to say how the period varies with the temperature in solid bodies at low temperatures. But the spectroscope shows that it does not change much at high temperatures.

The only possible way of obtaining an idea would be to extend the spectroscopic investigation even further than it has been done by Abney; either photographically or by the thermopile. We will assume, however, that as the bodies cool, their molecular vibrations, if altering at all as to period, tend to become slower, as well as of smaller amplitude. Let us consider the limiting condition of propagation of waves of longitudinal displacement. There seems no reason for supposing that the velocity of propagation would fall off till we come to waves of wave-length comparable with molecular distances—for instance with the mean free path. Now, by experiments in diffusion, it seems that the mean free path in oxygen is of the order of 5.6×10^{-6} cm.; in sugar solution it is 10^{-5} of this, or 5.6×10^{-11} cm.; while in solids it is probably much less. The size of the molecule, however, seems to be of the order 5.8×10^{-8} cm., so this will give our superior limit in solids and liquids.

Suppose that the smallest possible wave-length is the diameter of a molecule, and that the velocity of propagation is the same as that of sound down to this limit. Then, if V be the velocity of propagation, or the number of vibrations per second, and λ the wave-length in water, we have

$$n = \frac{V}{\lambda} = \frac{1.4 \times 10^5}{5.8 \times 10^{-8}} = 2.4 \times 10^{12}.$$

But it is unlikely that we could get a wave-length anything like so

small as this, so let us take as our limiting value the wave-length equal to a thousand molecular diameters. This gives us for the limiting frequency

$$n = 2.4 \times 10^9.$$

Comparing this with n for the A line, which is 4×10^{14} , we see that it is about a million times too slow to produce any effect on molecules vibrating so as to emit red light. But bodies at the ordinary temperature might possibly vibrate slowly enough to be influenced directly, though this is unlikely. It is rather surprising that the numbers are as comparable as they seem to be. If we perform the same operation for gases, putting $\lambda = 1000$ mean free paths, we get for oxygen $n = 5 \times 10^6$. Here the discrepancy is a thousand times as great; so that if longitudinal vibrations are to be considered as likely to produce any effect, they will be considerably more likely to do so if transmitted through solids or liquids than through gases.

We have still got the ether to fall back on, and there we are safe, for there is no reason why vibration of the right period should not be transmitted through it.

The experiments with tubes, however, seem to point exclusively to the air as the medium through which vibrations are to be transmitted, and that may be fairly regarded as unlikely. If the theory of synchronous vibrations can be disproved at all by experiment, then Abel has at all events made the most telling experiment against it; there may, of course, be other experiments, and these may point in the opposite direction, but the author has failed to learn of them. Still, in the light of what has been published on the subject, there is little doubt that our natural hesitation to accept a theory of vibrations is justified by a consideration of the facts. On the other hand, if we admit that vortex motion may exist, it will account for some of the effects observed in the neighborhood of violent explosions. The most important effect to be accounted for is the capriciousness of explosions. Instances are so numerous that it is hardly worth while to dwell upon them in detail; but take the famous explosion at Bremerhaven, for instance, and it is curious to note the way in which the bystanders seemed actually singled out for injury, and that not always from flying *débris*. Such effects as these are difficult to account for on any theory of uniform propagation of wave-motion. On the other hand, any of the observed phenomena of propagation of explosion are as well explained by vortex propagation as by wave-motion. There is no reason why the two states of propagation should not exist together,

varying in their relative importance according as the explosion is of long or short duration. In ordinary cases of detonation, we may imagine the shocks to be given by the explosion gases before any considerable breakdown has taken place.

Raschig has studied the fulminating compound obtained by Berthelot nearly a hundred years ago by the action of ammonia upon silver oxide. For the preparation of the substance, a solution of silver nitrate was precipitated with sodium hydrate, and the silver oxide washed by decantation. For each grain of silver nitrate used, there were poured upon the silver oxide 2 cubic centimetres of an ammonia solution containing 25 per cent. of NH_3 . The oxide of silver dissolved readily, leaving only a slight turbidity. The solution thus obtained was divided into several portions, each being placed in a porcelain dish about 10 cm. in diameter, so proportioned that no dish contained the oxide from more than one gram of the nitrate. Each dish was covered with a watch-glass and allowed to stand for 16 to 20 hours. The ammonia evaporated and the fulminating silver was deposited as a black, crystalline mass. After washing, it was analyzed by digestion with very dilute sulphuric acid, by which a residue of metallic silver was generally left. The dissolved silver was precipitated with hydrochloric acid, and in the filtrate the ammonia was determined as platino-chloride. The results of sixteen analyses gave ratios which were very close to three atoms of silver for one of nitrogen; leading to the formula NAg_3 . Other samples of the substance, prepared by warming the ammonia solution of the silver oxide on the water bath, or by precipitating it with alcohol, gave the same ratio on analysis. It explodes by the slightest concussion when dry, and requires great caution in handling even when moist. It is soluble in ammonia and in potassium cyanide. (*Liebig's Ann.* **233**, 93-101, April, 1886; *Am. Jour. Sci. (abstr.)* **32** [3], 232, Sept., 1886.)

Isaac Friedenwald, Baltimore, Maryland, has published Part I of an "Index to the Literature of Explosives," prepared by Prof. Charles E. Munroe, U. S. N. A., which contains the titles of all papers relating to explosives or explosions which have appeared in *Am. Jour. Sci.* 1819-1886; *Phil. Trans. Roy. Soc.* 1665-1882; *Jour. Roy. U. S. Inst.* 1857-1885; *Proc. U. S. Nav. Inst.* 1874-1885; *Revue d'Artillerie*, 1871-1884; *H. M. Inspect. Explosives*, 1873-1885; making in all 442 separate publications. This index is intended to embrace not

only such articles as treat of the composition and of the chemical and physical properties of explosive substances, but also of their manufacture and use in the arts.

The *Army and Navy Gazette*, 27, 801, October 9, 1886, gives the following glowing account of the new French mortar shell: It is stated that the French Budget Committee intend recommending £5,000,000 for new armaments, in consequence of the discovery of an explosive substance which necessitates serious changes. General Boulanger some time ago had his attention drawn to the fact that the Germans were manufacturing shells charged with *hellhofite*,* which had produced the most terrific effect on earthworks and masonry. Germany has already 175,000 of these shells in store. At the same time, the discovery of another explosive substance of equal if not of greater force than the German *hellhofite* was made in France (*mélinite*), the composition of which is kept a profound secret. At the first trial at Bourges, a gun charged with a *mélinite* shell burst, and caused fearful ravages. However, Lieutenant-Colonel Déjo, of the 3d Battalion of Fortress Artillery, has fired the new shell from a mortar, with similar results to those obtained in Germany. Neither walls nor earthworks nor plates can resist the force of this new agent. The shell is 40 inches long, about 8 inches in diameter, and weighs 220 pounds. General Boulanger got a deputation to accompany him to Soissons; one of the new shells was thrown into an old fort, and after explosion nothing of the fort remained. The committeemen were immediately convinced. One French writer, dwelling on the destructive quality of these shells, says that had they been used against Paris in 1870 by the Germans, or in 1871 against the Commune, the capital could not have resisted for a week. During the Commune, one house in the Avenue des Ternes was riddled by no fewer than 85 shells, and yet it did not fall. Now one of the new shells, we are assured, would destroy a whole block of houses. On the one hand, we are assured that *hellhofite* and *mélinite* have rendered all fortresses useless, and, on the other hand, we are informed that the profiles of all the new French forts are to be at once changed, so as to adapt them to the new order of things.

The *Jour. Mil. Service Inst.* 7, 339-349, Sept., 1886, contains a rather rough translation by Major G. W. McKee, U. S. A., from the

* *Vide* Proc. Nav. Inst. 8, 450; 1882, and 11, 771; 1885.

Spanish of Adolfo Carrasco,* entitled "The Employment of Dynamite as a Bursting Charge for Artillery Projectiles." Mr. Carrasco details the composition and properties of dynamite, discusses its practical effects against armor, as shown by Folger's experiments, and considers its efficiency in projectiles, adopting the conditions set forth by us.† He then reviews the methods used and the results obtained in various experiments which have been made in firing projectiles charged with this agent, and after describing the dynamite air-gun and its use, he says: "Such an invention, neither by its arrangement, manipulation, nor effects, can be ranked as artillery, nor can we expect from its shots that which we do from projectiles charged with dynamite, as Lieutenant Zalinski has reported to his Government, and therefore it is useless to discuss it further here, what has been said sufficing to justify its exclusion." In connection with the Point-Lobos experiments, where the gun burst at the third round, he quotes Colonel Kelton as considering the results very satisfactory, since they had demonstrated the possibility of employing dynamite in shells. Much space is given to the experiments by the Snyder method, and this method seems to have made so favorable an impression upon Mr. Carrasco, that, in marking out a program of experiments for the purpose of verifying the results already obtained, and of proving the possibility or impossibility of the use of dynamite in projectiles, he seems to have decided to use the Snyder system in the firing trials.

It is interesting to read this *résumé* in connection with Commander Barker's account of his experiments in firing dynamite under service conditions, published in this number of our proceedings.

The Flood Rock explosion has naturally given rise to much literature on the subject, and among others we notice the paper by General John Newton, "The Improvement of East River and Hell Gate," *Popular Science Monthly*, 28, 433-448, Feb., 1886; a note in the *Rivista di Artiglieria e Genio*, I, 160-170; 1886; an account of the blasting operations at Hell Gate, by L. F. Vernon-Harcourt, *Proc. Inst. Civil Eng.* 85, 1-13; 1886; and another, "The Hell Gate Improvement," by Lieutenant George McC. Derby, U. S. A. (one of General Newton's assistants), in *Sanitary Engineer*, Dec. 3, 1885.

* Memorial de Artilleria, Nov., 1885.

† Van Nostrand's Eng. Mag. 32, 3, Jan., 1885; Proc. Nav. Inst. 11, 291; 1885.

This last is reprinted nearly in full in the *Illustrated Catalogue of the Rand Drill Company*, New York, 97-109; 1886. All of these are illustrated, the latter two especially so, as they show the methods of driving and charging and firing the mine, the nature and extent of the obstructions to be removed, and the appearance of the blast. The operations at Flood Rock are also noticed by M. G. Cerbelaud in his "Emploi de la Dynamite pour le Sautage des Grosses Mines," *Mem. Soc. Ingénieurs Civils*, 792-805, Dec., 1885.

We are indebted to General H. L. Abbot for six exquisite photographs of the Flood Rock explosion. Two of them were taken, one just before, the other just after the explosion, from a height of 260 feet above the water level. The other four were taken at the firing station, it being 1100 feet from the hoisting tower on Flood Rock. Of these, the first was taken just before the explosion, and the others at 0.2, 0.6 and 2.0 seconds respectively after the explosion. The first two views show that ignition by sympathy was transmitted so rapidly as to be practically instantaneous over the entire area of the rock, and that no failure occurred in any of the galleries. In a word, they demonstrate the entire success of this new mode of ignition. The height of the tallest jet was found to be about 160 feet. The charge of the mine is stated to have consisted of 240,399 pounds of rackarock and 48,537 pounds of dynamite No. 1.

We are indebted to General Abbot also for advanced sheets of his reports on the "Earth Wave at the Destruction of Flood Rock," and of his "Tests of Rackarock." In the first the data are given of the seismographic observations made at eight different stations, situated at distances of from about eight to one hundred and eighty-three miles from Flood Rock. From the discussion of these data the conclusions are reached that these observations indicate (1) an extraordinary velocity of wave-translation in both directions observed, which confirms General Abbot's deductions from the Hallet's Point and certain torpedo explosions,* that "the more violent the initial shock, the higher is the velocity of transmission." At Flood Rock the charge was about six times as large as at Hallet's Point, and the velocity was from two to three times as great over essentially the same route. (2). The uniformity of velocity to the northward, where the strata consist largely of homogeneous gneiss rock, and where the

* *Am. Jour. Sci.* 15 [3], 178; 1878.

velocity even for 175 miles exceeded 20,000 feet per second. (3). The varying velocity which appeared to characterize the wave moving to the eastward, through the drift formation of Long Island. Here there seems to have been a gradual increase of velocity, followed by a decrease as the wave advanced; but on the whole a decidedly less rapid rate is indicated than in traversing solid rock, as might be expected in media of varying density and elasticity. This result, although not inconsistent with the Hallet's Point observations, was not discovered from them, except as to the decrease in velocity as the wave disappeared. This is the only point where the four deductions from the earlier observations are modified by this later and more accurately observed explosion.

The Flood Rock explosion appears to have caused a continuous earth-tremor, which, observed under a magnifying power of about 18, lasted about one minute throughout the whole region covered by the observations, the maximum disturbance leading the advance, or nearly so, for at least fifty miles. At extreme ranges the tremor appears to have broken up into successive waves with well-marked intervals between them. These facts, the instantaneous nature of the explosion shown by the photographs, and the varying rates of advance through strata not homogeneous, appear to warrant the conclusion that the oscillation followed different routes to any given point—some near the surface and others at greater depths, where more dense and elastic strata produced changes in the direction of the wave-front and yielded higher velocities.

The whole subject is evidently too complex to warrant definite conclusions as to the velocity of ordinary earthquake waves, where the intensity of the original disturbance must always remain unknown.

The tests of rackarock showed that a mixture containing 21 per cent. of nitrobenzol (sp. gr. 1.33) was the most efficient; that it was important to have the potassium chlorate used perfectly dry; that the resulting intensity does not differ, whether the explosive is loosely or solidly compacted in the can; that an explosion of the first order is certainly obtained when the charge is fired by two service fuses, each containing 24 grains of fulminating mercury in a copper cap; that the mean pressure obtained in the experiments was 108 per cent. of that of dynamite No. 1; that the contractor supplied for Flood Rock an explosive of much higher intensity than was exacted by the terms of his contract.

Gen. Abbot concludes: "This high intensity, joined to the advantages of entire safety in transportation, exemption from all danger in case of accidental exudation of the fluid from loaded holes, and other practical merits discovered in charging the mine, in my judgment more than confirm the wisdom of your (Gen. Newton's) selection of this new explosive in preference to any form of dynamite for use in a work of this exceptional magnitude."

We are in receipt of a pamphlet from the Rendrock Powder Co., New York, which describes the method of preparing rackarock for use, and of adjusting the primers, and contains a report of an examination of rackarock by George G. André, M. E., etc. etc. In addition to the other advantages claimed for this substance, he asserts that the gases from its explosion are of a much less harmful character than those from gun-cotton or dynamite.

The success which has attended the use of rackarock, panclostite and hellhofite, has led Dr. Hermann Sprengel to seek to establish his claims to priority of invention. The result has been a series of articles in the *Chemical News*, 52, 215, 271 and 295; 1885, and these have been gathered together, with extracts from various sources, and published by Dr. Sprengel under the title "The Hell-Gate Explosion and so-called Rackarock." From this we learn that while Dr. Sprengel invented his safety explosives in 1870, patented them in England April 6 and October 5, 1871, and published an account of them in August, 1873, Mr. Divine filed a caveat for his invention in the U. S. Patent Office January 9, 1871, though he did not patent it until December 7, 1880. To Dr. Sprengel, then, belongs the priority due to publication, and also the credit of being the first to recognize and point out the general principles which govern the manufacture and mode of action of this very numerous and very important class of explosives.

From the equations ordinarily found in our textbooks, it would appear that when potassium chlorate is heated it is resolved into potassium chloride and oxygen; but Frank L. Teed finds, in his researches on "The Decomposition of Potassium Chlorate by Heat," *Chem. News*, 52, 248; 1885, that the reaction is by no means so simple, but that we have also potassium perchlorate, formed thus:



so that for every 74.5 parts of potassium chloride produced there should be 24 parts of oxygen evolved; also, that when the potassium chlorate shall have yielded 7.84 per cent. of oxygen, all the chlorate is decomposed and nothing but perchlorate and chloride remains. Any further oxygen evolved results from the decomposition of the perchlorate. When manganese binoxide is heated with the chlorate, no perchlorate is formed. Dr. Armstrong thought these results indicated a higher molecular weight for the salt than the formula used requires.

In the *Chem. News*, 53, 145-147; 1886, E. J. Maumené, under the same title, calls attention to the fact that the reactions of potassium chlorate occupied his attention so long ago as 1845-46, his results being published in *Ann. de Chim.* 18, 41, and that later he obtained similar results to those quoted above; but he makes the reaction still more complex.

Dr. H. Carrington Bolton finds that potassium or sodium peroxide may be readily prepared by heating the nitrate to fusion in a test tube until oxygen is freely evolved and then dropping in pellets of the metallic radical. The metal burns with a bright light and forms the peroxide, which dissolves in the molten mass.

On attempting to examine in the same way the action of sodium upon melted potassium chlorate a violent explosion occurred, projecting fragments of the test tube and the melted salt into the face and over the person of the operator. The explosion was instantaneous, and accompanied by a loud report. On repeating this with suitable precautions, using a stouter tube surrounded by a metallic cylinder, similar explosions resulted, without, however, breaking the glass. Pellets of sodium no larger than a grain of barley cause sharp reports the moment they reach the surface of the melted chlorate. (*Chem. News*, 58, 289; 1886.)

In connection with the recent rapid advances made in the liquefaction of gases, the following statement of Faraday's, drawn from the *Jour. Sci. Roy. Inst.* 16, 229-240; 1823, entitled "Historical Statement Respecting the Liquefaction of Gases," may prove interesting:

The *Phil. Trans.* for 1797, p. 222, contains an account of experiments made by Count Rumford to determine the force of fired gunpowder. Dissatisfied both with the deductions drawn and the means used previously, that philosopher proceeded to fire gunpowder in

cylinders of a known diameter and capacity, and closed by a valve loaded with a weight that could be varied at pleasure. By making the vessel strong enough and the weight sufficiently heavy, he succeeded in confining the products within the space previously occupied by the powder. The Count's object induced him to vary the quantity of gunpowder in different experiments, and to estimate the force exerted only at the moment of ignition, when it was at its maximum. This force, which he found to be prodigious, he attributes to aqueous vapor intensely heated, and makes no reference to the force of the gaseous bodies evolved. Without considering the phenomena which it is the Count's object to investigate, it may be remarked that in many experiments made by him, some of the gases, and especially carbonic-acid gas, were probably reduced to the liquid state. The Count says :

“ When the force of the generated elastic vapor was sufficient to raise the weight, the explosion was attended by a very sharp and surprisingly loud report ; but when the weight was not raised, as also when it was only a little moved, but not sufficiently to permit the leather stopper to be driven quite out of the bore, and the elastic fluid to make its escape, the report was scarcely audible at the distance of a few paces, and did not at all resemble the report which commonly attends the explosion of gunpowder. It was more like the noise which attends the breaking of a small glass tube than anything else to which it could be compared. In many of the experiments in which the elastic vapor was confined, this feeble report attending the explosion of the powder was immediately followed by another noise totally different from it, which appeared to be occasioned by the falling back of the weight upon the end of the barrel after it had been a little raised, but not sufficiently to permit the leather stopper to be driven quite out of the bore. In some of these experiments a very small part only of the generated elastic fluid made its escape. In these cases the report was of a peculiar kind, and, though perfectly audible at some considerable distance, yet not at all resembling the report of a musket. It was rather a very strong, sudden hissing, than a clear, distinct and sharp report.”

In another place it is said : “ What was very remarkable in all these experiments in which the generated elastic vapor was completely confined, was the small degree of expansive force which this vapor appeared to possess after it had been suffered to remain a few minutes, or even only a few seconds, confined in the barrel ; for upon

raising the weight by means of its lever and suffering this vapor to escape, instead of escaping with a loud report, it rushed out with a hissing noise hardly so loud or so sharp as the report of a common air-gun, and its effects against the leather stopper, by which it assisted in raising the weight, were so feeble as not to be sensible." This the Count attributes to the formation of a hard mass like a stone within the cylinder, occasioned by the condensation of what was, at the moment of ignition, an elastic fluid. Such a substance was always found in these cases, but when the explosion raised the weight and blew out the stopper, nothing of this kind remained.

The effects here described, both of elastic force and its cessation on cooling, may evidently be referred as much to carbonic acid, and perhaps other gases, as to water. The sudden strong hissing observed as occurring when only a little of the products escaped, may have been due to the passage of the gases into the air with comparatively but little water, the circumstances being such as were not sufficient to confine the former, though they might the latter; for it cannot be doubted but that in similar circumstances the elastic force of carbonic acid would far surpass that of water. Count Rumford says that the gunpowder made use of, when well shaken together, occupied rather less space than an equal weight of water. The quantity of residuum before referred to, left by a given weight of gunpowder, is not mentioned, so that the actual space occupied by the vapor of water, carbonic acid, etc., at the moment of ignition, cannot be inferred. There can, however, be little doubt that when perfectly confined they were in the state of the substances in M. Cagniard de la Tour's experiments.

When allowed to remain a few minutes, or even seconds, the expansive force at first observed diminished exceedingly, so as scarcely to surpass that of the air in a charged air-gun. Of course, all that was due to the vaporization of water and some of the other products would cease as soon as the mass of the metal had absorbed the heat, and they would concrete into the hard substance found in the cylinder; but it does not seem too much to suppose that so much carbonic acid was generated in the combustion as would, if confined on the cooling of the apparatus, have been equal to many atmospheres, but that, being condensable, a part became liquid, and thus assisted in reducing the force within to what it was found to be.

The Pharmaceutical Record, 6, 349-350; 1886, publishes a "Tabulated List of Explosive Substances," by Charles D. Lippincott,

which embraces such articles as are likely to explode when triturated singly or when mixed with other substances, and also of such as are liable to undergo spontaneous combustion. The list is prepared for the drug trade, and contains some curious information.

A recent publication, which may be found of value in connection with the study of gun-cotton, is issued in the form of a thin pamphlet by C. F. Cross and E. J. Bevan, and entitled "Cellulose." These authors have given much attention to the experimental study of this little-known but commonly-occurring body, the results having been published in the *Jour. Chem. Soc.* and elsewhere, and summarized here. The pamphlet has been written to impress upon the younger chemists the importance of further research in this rich but much neglected field of investigation.

U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

FEBRUARY, 1887.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XIII.

It is admitted that among the methods proposed for the estimation of the nitrogen contents of nitrates or nitric esters, the speediest and most accurate is that which is based upon Crum's reaction, *i. e.* by shaking with an excess of sulphuric acid and mercury and measuring the nitrogen oxides evolved. It will be generally admitted also that the most convenient and accurate means of applying this method, especially for fluids, or for substances easily soluble in water, is found in the nitrometer described by Lunge.† This instrument is now generally made use of for testing nitroglycerine in the factories, and likewise for the analysis of the various kinds of dynamite.

For the direct analysis of explosives which contain nitroglycerine mixed with other bodies, such as nitrocellulose and the like, other means were considered necessary, for the bodies could not be dissolved, and so gotten into the nitrometer. In order to use the Crum reaction with these bodies, W. Hempel‡ constructed another form of nitrometer. Hampe,§ in an extended discussion of nitrometric methods, pronounces the Hempel method convenient, easily performed, and very exact for all bodies which evolve nitrogen oxide

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address Torpedo Station, Newport, R. I.

† Ding. Poly. Jour. **228**, 447, 1878 ; **231**, 522, 1879 ; **243**, 421, 1882 ; **258**, 361, 1885.

‡ Zeitschrift für Anal. Chem. 82 ; 1881.

§ Ueber die Analyse der Sprengkörper, 18 ; 1883.

exclusively. Partly in order to be able to analyze bodies containing carbon dioxide, and partly on account of the expensiveness of Hempel's instrument, Hampe devised another method, which depends upon the fact that the nitrogen oxide evolved by the Crum reaction is converted into nitric acid by means of oxygen and hydrogen dioxide, and that this acid is then nitrated with a normal soda solution, thus following the analogous method of Schloesing for the estimation of nitrogen by ferrous chloride, which is now almost entirely abandoned for the gasometric method. The Hampe method does not appear to be employed to any extent—Lunge not having found it in use in a single factory visited—probably on account of its indirectness. When, as is often the case with a new dynamite, it is necessary, for complete analysis, to separate the soluble inorganic nitrates from the esters (nitrocellulose and nitroglycerine) by extraction, then the Lunge method is still the simplest and most convenient. Only in direct analyses of guhr-dynamites and pyroxylin has it appeared that the Hempel, or perhaps the Hampe, method was to be preferred.

A recent discussion of these methods has been published by Lubarsch,* who disputes the assertion that Hempel's nitrometer is convenient and easy of use; on the contrary, to attain correct results with it requires unremitting necessity for the quickest possible work in the introduction of the substance into the evolution chamber, while great skill and experience are required in filling the latter with mercury. Its use also includes no less than three sources of error—viz.: loss of material during solution; loss of nitrogen oxide while charging the vessels, and finally loss from the air-bubbles unavoidably present. For porous gun-cotton especially the process is hardly feasible. For explosives containing carbonic acid it is unsuitable in principle. Lubarsch considers Hampe's method too indirect for practical use. On this account he has devised an instrument which he calls a "reversion nitrometer." Lunge urges that this instrument is a step backward, as mercury must be added or withdrawn from the apparatus to get the desired quantity; the diameters of the two tubes are unlike, and hence the meniscus depressions are unequal; the use of a carbon-dioxide generator is onerous, and the neutralization of the lime in the gun-cotton unlikely to take place uniformly; while the cost of the instrument is 50 M., as against 13 M. for Lunge's.

Lunge has now made an addition to his nitrometer by which he claims to have secured all the advantages of Hempel's and Lubarsch's

* Programm des Friedrich's-Realgymnasiums, Gartner's Verlag, Berlin, 1885.

instruments at almost no expense, while maintaining the superiority for simplicity and readiness of use which his instrument has heretofore possessed. This addition consists of a thistle tube, whose stem is bent twice and then inserted in a rubber cork, which fits the funnel of the nitrometer. In use, as much of the substance to be tested is weighed out as the capacity of the nitrometer calls for (50, 100 or 140 cm.³), and this, whether kieselguhr-dynamite, pyroxylin, etc., is placed in the funnel of the nitrometer. Then the rubber stopper and doubly bent thistle tube are inserted, and from 2 to 3 cm.³ of concentrated H_2SO_4 are poured in the thistle. Naturally some of the acid remains in the bend of the tube and seals it, thus preventing the nitrogen oxides liberated during solution from escaping. When the solution is completed the three-way cock is opened and the fluid is drawn down into the measuring tube. Of course the acid in the bent thistle is drawn down with the fluid, and it serves the purpose also of rinsing the tube. The rubber cork and thistle tube are now removed and the second rinsing is effected directly in the funnel. The analysis is now carried on as usual, and when completed the liquid is forced back into the funnel. It has never yet occurred that the cock has been obstructed by the kieselguhr mixed in the acid, though such difficulty might have been apprehended. It is clear that the carbonic acid present would, under these conditions, cause no error.

To show how good the results by this method are, Lunge cites those obtained by B. Lee, chemist to the dynamite factory at Isleton, Uri, Switzerland. He examined collodion gun-cotton which had been dried first at 40° C. and finally over H_2SO_4 . In Experiment I. the funnel of the nitrometer remained closed during the entire operation—that is, the H_2SO_4 for the rinsing, as well as that for the solution of the gun-cotton, was poured through the double-bent thistle tube. In Experiments II. and III., on the other hand, the dust on the sides of the funnel of the nitrometer was washed down with a little acid, and only after this were the rubber stopper and thistle inserted and the principal part of the acid run in. After the gun-cotton was dissolved and the solution drawn into the nitrometer the stopper and thistle tube were again removed and the rinsing carried on with uncovered funnel. The latter, therefore, only remained covered while the gun-cotton was dissolving, which was from three-quarters to one hour, the solution being accelerated by gentle shaking from time to time. During solution there was a considerable evolution of colorless gas-bubbles, due, apparently, to the decomposition of the carbonates contained

in the gun-cotton. As this decomposition takes place outside of the measuring tube, the CO_2 cannot cause an error in the measurement of the nitrogen oxides, as is the case when Hempel's or Lubarsch's nitrometers are used. The results are as follows:

No.	Weight Gun-Cotton Used in Grams.	Vol. Gas Measured.	Barometer.	Thermom- eter.	Nitrogen per cent.
I.	0.5252	113.1 cm. ³	725 mm.	17°	12.09
II.	0.5159	111.3	725	18	12.07
III.	0.5120	110.3	725	18	12.05

This proves that the method is an accurate one, even in the case where it is carried out, as in II. and III., in the simplest way.

The appearance of the above communication in the *Chemischen Industrie*, 273; 1886, led G. Alberts, chemist at the Nobel dynamite factory at Avigliana, near Turin, to describe his method of manipulation. Mr. Alberts has for the past two years been making analyses of gun-cotton with a Lunge nitrometer in the following way: The specimens are dried for about two hours at 40° C., then rubbed through a fine brass sieve; then an average sample of about 10 grams is taken and dried over H_2SO_4 to constant weight. A suitable quantity of this (about 0.48 gram) is weighed out in a 10 cm.³ glass flask with ground stopper; the 140 cm.³ nitrometer is prepared in the usual way, and then about 5 cm.³ of concentrated H_2SO_4 are poured into the flask containing the gun-cotton, mixed with a platinum wire, transferred to the funnel of the nitrometer and drawn into the measuring tube as quickly as possible. The rinsing is several times effected by pouring portions of about 3 cm.³ each of concentrated H_2SO_4 into the flask and transferring as before. Finally the platinum wire and funnel are washed in the same way. The total amount of acid used is from 15 to 20 cm.³ The CO_2 present in the gun-cotton escapes during the treatment, and no development of gas has been observed in the funnel of the nitrometer. The following figures indicate the accuracy of the method:

Ash Contained in Sample.	Nitrogen Observed.	Nitrogen in Ash Free Sample.
0.86 per cent.	13.40 per cent.	13.52 per cent.
2.40	13.20	13.53
2.16	13.24	13.53
1.80	13.30	13.54
2.60	13.20	13.55

The samples analyzed all came from the same nitrating process;

the difference in the amount of ash may be due to difference of treatment after nitration.

Alberts believes this method preferable to that with the bent thistle tube just proposed by Lunge, because not more than five minutes is required for getting the gun-cotton in the measuring tube, and the whole operation is completed in one hour; while with the thistle tube much time is spent in waiting for the gun-cotton to dissolve, and, besides, the oxides of nitrogen evolved in the funnel are lost. Lunge denies this latter assertion, as the liberated oxides are redissolved by the excess of H_2SO_4 present. The time lost in waiting for solution may be avoided by pulverizing the cotton as Albert does, and allowing it to enter the measuring tube before solution is complete. This will be better than treating in a separate flask, as that requires great skill and experience to avoid loss. ("The Analysis of Explosives," G. Lunge, *Ding. Poly. Jour.* **262**, 224-229; 1886.)

We have given in these Proceedings* the heat test as applied to dynamite and analogous nitroglycerine preparations. This has now been modified as follows:

Nitroglycerine preparations from which the nitroglycerine can be extracted in the manner described below must satisfy the following test, otherwise they will not be considered as manufactured with "thoroughly purified nitroglycerine" within the terms of the license.

This test, however, though at present looked upon as the most important, as far as testing the purity of nitroglycerine is concerned, is only one of several which any given sample of nitroglycerine preparation has to satisfy in order to establish its compliance with the definition of the license.

The test, although at present accepted as regulating and defining the meaning of the term "thoroughly purified," may, nevertheless, be modified or superseded if in the opinion of the Home Office such alteration may at any time be deemed necessary.

The apparatus required is: (1.) Test tubes from $5\frac{1}{4}$ to $5\frac{1}{2}$ inches long, and of such diameter that they will hold from 20 to 22 cubic centimetres of water when filled to the height of 5 inches. (2.) The test tubes to be fitted with perforated corks, which should be conical, so as to fit all the tubes equally well. The perforations hold glass rods provided with a hook of glass or platinum to hold the test paper.

* 5, 11; 1879.

(3.) The heating apparatus as prescribed with the original Government heat test.*

The test paper used is prepared as follows: 45 grains of white starch previously washed with cold water are added to $8\frac{1}{2}$ ounces of distilled water; the mixture is stirred, heated to boiling and kept gently boiling for ten minutes; 15 grains of pure potassium iodide (*i. e.* which has been recrystallized from alcohol) are dissolved in $8\frac{1}{2}$ ounces of distilled water. The two solutions are thoroughly mixed and allowed to get cold. Strips or sheets of white English filter paper previously washed with water and redried are dipped into the solution thus prepared and allowed to remain in it for not less than ten seconds; they are then allowed to drain and dry in a place free from laboratory fumes and dust. The upper and lower margins of the strips or sheets are cut off, and the paper is preserved in well-stoppered or corked bottles and in the dark. The dimensions of the pieces of test paper used are about $\frac{4}{10}$ inch by $\frac{8}{10}$ inch (10 mm. by 20 mm.).

The standard-tint paper is prepared by making a solution of caramel in water of such concentration that when diluted one hundred times (10 cm.³ made up to one litre) the test of this diluted solution equals the tint produced by the Nessler test in 1 cm.³ (?) of water containing 0.000075 gram of ammonia or 0.00023505 gram of chloride of ammonium. With this caramel solution lines are drawn on slips of white filter paper by means of a clean quill pen. When the marks thus produced are dry the paper is cut into pieces of the same size as the test paper previously described, in such a way that each piece has a brown line across it near the middle of its length, and only those strips are preserved in which the brown line has a breadth varying from $\frac{1}{2}$ mm. to 1 mm. ($\frac{1}{50}$ of an inch to $\frac{1}{25}$ of an inch).

The apparatus required for treating the sample to be tested consists of a wide-mouthed bottle of about 6 ounces capacity to which is fitted an India-rubber stopper having two perforations. Through one of these passes a bent tube, and through the other a filtering tube. The latter should have sufficient capacity to hold about 500 grains of dynamite. Within the bottle is placed a small test tube to receive the nitroglycerine filtering through.

About 400 grains of dynamite, finely divided, are placed in the filtering tube (a small piece of cotton-wool having previously been pushed into the contracted part of the tube) and made to fit it as

* *Loc. cit.*

evenly as possible by shaking and tapping; the upper surface is smoothed by gently pressing with a wooden rammer. Water is then poured on the top of the dynamite and allowed to sink into it by its own weight until a sufficient quantity of nitroglycerine has been displaced. The bent tube may then be connected with the filtering pump, or other means of reducing the pressure in the bottle, the displacement of the nitroglycerine being thus accelerated. The nitroglycerine collects in the test tube, and the operation is stopped before the water reaches the narrow part of the filtering tube. If any water should have passed through with the nitroglycerine, it should be removed with a piece of blotting-paper, and the nitroglycerine, if necessary, filtered through a dry paper filter.

In making the heat test, the thermometer is fixed so as to be inserted through the lid of the glass globe into the water (which is to be steadily maintained at a temperature of 160° F.) to a depth of $2\frac{3}{4}$ inches. Fifty grains of the nitroglycerine to be tested are weighed into a test tube in such a way as not to soil the sides of the tube. A test paper is fixed on the hook of the glass rod so that when inserted in the tube it shall be in a vertical position. A sufficient amount of a mixture of half distilled water and half glycerine is now applied to the upper edge of the test paper by means of a camel's-hair pencil, to moisten the upper half of the paper; the cork carrying the rod and paper is fixed in the test tube, and the position of the paper adjusted so that its lower edge is half-way down the tube; the latter is then inserted through one of the perforations of the cover to such a depth that the lower edge of the test paper is just above the surface of the cover. The test is complete when the faint brown line which after a time makes its appearance at the boundary line between the dry and moist part of the paper equals in tint the brown line of the standard tint paper.

The nitroglycerine under examination will be considered as "thoroughly purified," within the terms of the license, whenever the time necessary to produce the standard tint as above described is not less than fifteen minutes.

The heat test for blasting gelatine and gelatine dynamite is applied by intimately incorporating 50 grains of blasting gelatine with 100 grains of French chalk. The mixture is to be gradually introduced into a test tube of the dimensions prescribed in the dynamite heat test, with the aid of gently tapping upon the table, between the introduction of successive portions of the mixture into the tube, so that

when the tube contains all the mixture it shall be filled to the extent of $1\frac{3}{4}$ inches of its height. The test paper is then to be inserted and the heat is to be applied in the manner prescribed for the dynamite heat test, and the sample tested is to withstand exposure to 160° F. for a period of ten minutes before producing a discoloration of the test papers corresponding in tint to the standard color test which is employed for governing the results of the dynamite heat test.

The test for liquefaction of blasting gelatine and gelatine dynamite is made by cutting a cylinder from the cartridge to be tested, whose length is about equal to its diameter, the ends being cut flat. The cylinder is then to be placed on end on a flat surface, without any wrapper, and secured by a pin passing vertically through its centre. In this condition the cylinder is to be exposed for one hundred and forty-four consecutive hours (six days) to a temperature ranging from 85° to 90° F. (inclusive), and during such exposure the cylinder shall not diminish in length by more than one-fourth, and the upper cut surface shall retain its flatness and the sharpness of its edge. If the specimen to be tested be not made up in a cylindrical form, the above test is to be applied with the necessary modifications.

The test for liability to exudation of blasting gelatine and gelatine dynamite requires that there shall be no separation from the general mass of the sample to be tested of a substance of less consistency than the bulk of the remaining portion of the material under any conditions of storage, transport or use, or when the material is subjected three times in succession to alternate freezing and thawing, or when subjected to the liquefaction test hereinbefore described. (*Ann. Rept. H. M. Inspectors Explosives*, 1884 ; 63.)

Dingler's Polytechnisches Journal, **262**, 128-134, October, 1886, contains a valuable paper by Prof. Franz v. Rziha upon "The Mechanical Efficiency of Explosives." According to the researches of Bunsen and Schischkoff,* 1 kilo. of gunpowder develops a theoretical power of 67410 km., according to Stadler† 88157 km., and to Berthelot‡ 161500 km.; but these are all superseded by the results obtained by Roux and Sarrau.§ These latter exploded several varieties of gunpowder and other explosives in a calorimeter in the same way as

* Pogg. Annalen, **12**, 321 ; 1857, and Proc. Nav. Inst. **5**, 538 ; 1879.

† Zeit. d. oester. Ing. und Arch. **41** ; 1886.

‡ Sur la Force de la Poudre, Paris, 1871.

§ Comptes rend. **77**, 138, 478 ; 1873.

Bunsen and Schischkoff had done, and they obtained the following results :

One Kilo. of the Explosive.					Heat Units per 425 K.	Total Theoretical Work in Km.
Blasting powder, KNO ₃ 62%, S 20%, C 18%,					570.2	242335
Musket	“	“	74	10.5 15.5	730.8	310590
Cannon	“	“	75	12.5 12.5	752.9	319982
Sporting	“	“	78	10 12	807.3	343102
Gun-cotton					1056.3	448927
Dynamite, nitroglycerine 75%, kieselguhr 25%,					1290.0	548250

From the value obtained for 75 per cent. dynamite we may deduce the theoretical work of one kilo. of nitroglycerine as follows (allowing six per cent. of the nitroglycerine to be consumed in heating the kieselguhr): $(548250 \times 100) \div (75-6) = 794565$ km. Again, from the values found for gun-cotton and nitroglycerine we may calculate the theoretical work of explosive gelatine composed of nitroglycerine 92 per cent. and gun-cotton eight per cent. thus: $(794565 \times 92) + (448927 \times 8) \div 100 = 766913$ km. According then to the researches of Roux and Sarrau, the four explosives principally used rank as follows :

Explosive.	Theoretical Work in Km.	Relative Value.
Blasting powder with 62% saltpetre, . . .	242335	1.00
Dynamite with 75% nitroglycerine, . . .	548250	2.26 1.00
Explosive gelatine with 92% nitroglycerine, . . .	766913	3.16 1.40
Nitroglycerine,	794565	3.28 1.45

The last two columns give the relative efficiencies of these four explosives as deduced from theory. Approximately the same values have been obtained in practice in blasting. Thus experience has shown that to move one cubic metre of the same kind of rock, under precisely the same stratigraphic and other local conditions, by weight, two to three times as much blasting powder as dynamite will be required. Makuc,* director of the mines at Bleiberg, in a lengthy experience found the ratio for powder and dynamite to be as 1 : 1.84. From an extended experience in railway building, especially in the Buchberger cut, Von Pischof† found the following ratios for powder and dynamite :

* Oesterreichische Zeitschrift für Berg- und Hüttenwesen, 227 ; 1882 ; also Ding. Poly. Jour. 246, 186 ; 1882.

† Trauzl, Dynamit und Schiesswolle, 147, Vienna, 1870.

In medium hard syenite,	1 : 2.40
In hard syenite or granite,	1 : 2.57
In felsite or quartzite,	1 : 3.30

The mean of these four results gives a ratio of 1 : 2.53, while Roux and Sarrau find a theoretical relation of 1 : 2.26.

Experiments have given the following relations between dynamite and gelatine :

St. Gothard, railway,*	1 : 1.46
Zankeroda, mines,†	1 : 1.45
Tarnowitz, excavation,‡	1 : 1.41
Mannsfelder, excavation,§	1 : 1.33
Mean,	1 : 1.41

while theory requires 1 : 1.4.

In the tests by Trauzl’s method, where equal weights of the explosive are exploded in cavities in lead cylinders, and the efficiency measured by the increased volume of the cavities, the following results were obtained :

Author.	Dynamite.	Gelatine.	Nitroglycerine.
V. Friese || (Committee report),	1.00	1.26	
Münch,**	1.00	1.57	1.86
Trauzl,††	1.00	1.43	1.43
Dr. Klose,‡‡	1.00	1.50	1.80
Mean,	1.00	1.44	1.70

Here, again, we have a fairly close agreement with the theoretical values of Roux and Sarrau.

The theoretical efficiency of an explosive cannot be realized in useful work for several reasons—viz.: because of incomplete explosion ; because of the compression and chemical changes induced in

* Tetmajer, Nobel’sche Präparate, 37, Zurich, 1882.
† M. Georgi, Jahrbuch für das Berg- und Hüttenwesen im König. Sachsen, 1882.
‡ Zeitschrift für das Berg-, Hütten- und Salinenwesen, 191 ; 1882.
§ Ibid. 246 ; 1881.
|| Wochenschrift des oester. Ing. u. Architektenvereins, 144 ; 1883.
** Ibid. 205 ; 1882.
†† Trauzl, Ueber neue Sprengstoffe, 24, Berlin, 1883.
‡‡ Zeitschrift für das Berg-, Hütten- und Salinenwesen, 91 ; 1883.

the surrounding material; because of the energy expended in cracking * and heating † rock which is not displaced; because of the escape of considerable quantities of the gases through the blast hole and the fissures made by the explosion. In all probability the extent of this loss can never be determined by direct experiment, as the phenomenon of an explosion does not permit of close observation; nor can it be determined by comparison with the work done under other circumstances, as we are yet uncertain as to the so-called dynamic resistance of rock.

We are therefore met by a problem which for the present can only be solved by employing a technical analogy, and such a one is found in the firing from ordnance and small arms, where fortunately the work done by a powder charge has been determined with great precision. The use of the analogy is permitted because one can, according to the arrangement of the ball or tamping, shoot or blast with one and the same charge, and, therefore, with one and the same source of power, overcome resistance of two forms but of nearly equal magnitudes; and because, further, the process of burning the charge, whether in shooting or in blasting, is technically the same, for in each case the charge rests at the bottom of the cavity closed by means of the shot or tamping, and in each case the space occupied by the charge is increased through the chemical development of the gases so that the shot is moved forward in the bore or the tamping is compressed in the blast hole; and, finally, the practice of years has demonstrated that the greatest amount of useful work is realized either in shooting or blasting when certain relations of diameter, length and strength of walls on the one hand, and of size of charge on the other, have been attained.

Objections to the use of this analogy can only be based upon doubts as to whether the explosion is completed in the same time in both instances—that is, for the like release of power from the source—and whether the loss of gas is equal in both cases. These doubts are, however, so far as it is possible to observe, insufficient to prohibit the use of this analogy, since this is the only existing one, and the error connected with its use can in no case be great.

* Schell, *Beobachtungen über Gesteinschwingungen in der Grube*, in der *Zeitschrift f. d. Berg-, Hütten- und Salinenwesen*, 340; 1880, and 31; 1883; and M. Becker, *Allgemeine Baukunde des Ingenieurs*, 421; 1853.

† In rapid firing by artillery and infantry, from 10 to 15 per cent. of the theoretical work of the charge is spent in heating the piece.

Gen. Poncelet* states that a 12-kilo. shot thrown by a 4-kilo. charge attains an initial velocity of 500 m. per second, and calculates from this and from the work expended in the recoil of the piece that one kilo. of gunpowder develops an energy available for useful work of 38354 km.

Combes† cites the data of Poncelet, and gives in connection with it the capacity for useful work of powder as measured by the old French powder proof. This required that 92 grams of powder should throw a ball weighing 60 old French pounds = 29.37 kilos. a horizontal distance of $W = 225$ m., when the proof mortar was elevated $\alpha = 45^\circ$. From the initial velocity thus developed, $v = \sqrt{gW \div \sin 2\alpha}$, and from the equation for energy, $A = Qv^2 \div 2\alpha$, we deduce the useful mechanical work developed by the charge, $A = \frac{1}{2} QW = \frac{1}{2} (29.37 \times 225) = 3304$ km., from which we have for one kilo. of powder $A = 3304 \div 0.092 = 35913$ km.

Since the publication of these results immense advancement has been made in the science of ordnance, not only in the construction of guns and projectiles, but also in the invention of means for observing the pressures of the gases in the bore and measurements of the velocities of the projectiles (the latter by Boulangé's‡ method), so that the capacity of gunpowder for useful work may be deduced from the results of a large number of different experiments. In the following table a variety of such experiments are given for the purpose of obtaining a mean value. These have been quoted partly from the *Handbücher§ für die österreichischen Generalstabs-Offiziere*, and partly from the *Mittheilungen des Artillerie und Genie-Wesens*.

Notwithstanding the great variety of powders used, and the great differences which existed in the relations between the length and diameter of bore, size of charge and weight of projectile, and in spite of the fact that in these experiments the weights of the charges varied from .005 to 408.6 kilos., while that of the projectiles varied from .024 to 1000 kilos., yet there is an astonishing agreement in the values obtained in the last column. The constant for the useful work is taken by ordnance officers as being at least 40 metre-tons, and hence we will use this value, 43788 kilogram-metres, in the following discussion.

* *Traité de Mécanique industrielle* (Paris, 1834), 180.

† *Traité de l'Exploitation des Mines* (Paris, 1844); German of C. Hartmann (Weimar, 1852), 152.

‡ *Dingl. Poly. Jour.* **261**, 254; 1886.

§ Hauptmann Springer, Brünn, 1880.

Kind of Musket or Gun.	Weight of charge in kilos., <i>L.</i>	Weight of projectile in kilos., <i>Q.</i>	Observed initial velocity in metres, <i>v</i> .	Work done by charge in kilo-gram-metres.	Useful work per kilo. of powder $\frac{Qv^2}{2gL}$, km., $\frac{Qv^2}{2g}$.
Austrian infantry rifle, Wundt (old model).....	.005	.024	440.0	232	46464
Austrian infantry rifle, Wundt (new model).....	.005	.024	453.0	251	50200
Austrian 7 cm. field-gun.....	.350	2.900	299.0	13227	37791
“ 8 “ .....	.950	4.300	442.0	39069	41125
“ 9 “	1.500	6.400	448.0	65536	43690
Krupp's armor-piercing gun (old mod.)	205.000	776.700	502.4	9992000	48700
“ 40 cm. gun (1881 model).....	220.200	779.000	519.4	10716000	48664
“ 40 “ (1884 model).....	279.200	741.000	615.2	14300000	51071
French 34 cm. gun.....	164.000	420.000	600.0	7710000	47012
“ 37 “	246.500	535.000	600.0	9821000	39842
Woolwich 23 cm. gun.....	149.800	172.500	728.6	5196000	34640
“ 34 “	283.700	567.500	625.2	11310000	39866
Elswick 23 cm. gun.....	90.800	172.500	671.0	3960000	43612
“ 41 “	408.600	817.000	616.1	15810000	38693
“ 43 “	350.500	1000.000	558.8	15930000	45448
Mean.....					43788

If according to Roux and Sarrau we place the theoretical work of one kilo. of powder at 319982 km., then we may reckon that the available work, when fired in gun or musket, is $\mu = (43788 \times 100) \div 319982 = 13.71$ per cent.

In default of other data and methods of research, the useful effects of blasting charges of powder may also be placed at 13.71 per cent. The same value is also permissible for other explosives, since the foregoing discussion shows that the practical efficiency of explosives stands in the same relation as their theoretical efficiency. Consequently we have:

Explosive.	Theoretical Work, Km.	$\mu = 13.71$ gives Useful Work, Km.	The Ratios of these Values.
Blasting powder 62% saltpetre, . .	242335	33224	1.0 ...
Dynamite 75% nitroglycerine, . .	548250	75165	2.2 1.0
Explosive gelatine 92% nitroglycerine, . .	766913	105144	3.2 1.4
Nitroglycerine,	794565	108935	3.3 1.5

The useful work of a blasting charge is employed two ways—viz.: partly in shattering the rock and partly in throwing or displacing the shattered masses. It is a familiar engineering problem to reduce the projectile force of a blast to a minimum (though for practical reasons it cannot be wholly dispensed with) by means of suitable-sized charges,

properly located in blast holes of estimated dimensions, and so avoid the cannonading of which the workmen are so fond. With the discovery of at least approximately correct values for the useful work of charges, we are now able to demonstrate the correctness of this principle.

The volume of the shattered rock is computed by the formula $V = k \times t^3$, in which k is a coefficient determined by practice, and t is the depth of the blast hole. For example, $t = 0.75$ m. and $k = 0.8$;* then $v = 0.34$ m³. In a certain stone of specific gravity = 2.8 the weight of explosive will be $Q = 0.34 \times 2.8 \times 1000 = 952$ k.

If for simplicity it is assumed that the charges were at less than 45° and that the mass is only thrown 10 m., then the work of projection will be $A = \frac{1}{2} Q W = \frac{1}{2} (952 \times 10) = 4760$ km.

The blast acts in a hole 75 cm. deep and 30 mm. in diameter, which is charged to a depth of 20 cm. with dynamite of 1.6 sp. gr. and containing 75 per cent. of nitroglycerine. This charge weighs, therefore, $L = (7 \times 20 \times 1.6 \times 1000) \div 1000000 = 0.22$ k., and has a capacity for useful work of $a = 75165 \times 0.22 = 16536$ km. This action of projecting, then, has consumed $(4760 \times 100) \div 16536 = 29$ per cent. of the available useful work; whence it may be seen that, however general the calculation, this throwing of the *débris* is an evil, and represents a not-to-be-underestimated loss of available energy.

The *Engineering News* Publishing Co., New York, 1886, reprint from their journal the report of Capt. William H. Bixby, U. S. A., to the War Department on "New Ordnance Material in Europe," from which we extract the following account:

During the writer's visit to Magdeburg he had the opportunity of examining Gruson's new explosive of 1881,† which seems especially adapted to all military purposes wherever a safe but violent explosive is required. This explosive is composed of two ingredients which can be transported with perfect safety, are mixed only for use, and can be re-separated with ease at any subsequent moment. It is more powerful than nitroglycerine, safer than dynamite, produces no unpleasant effects upon those who handle it, and is cheap. In 1881-2 it was being tried by the German Government, but, as usual, all results were kept secret. The composition of this explosive is still kept partially secret. One ingredient is strong nitric acid, and the other

* Reiha, Lehrbuch der Tunnelbaukunst, I, 189, 192, 197.

† Proc. Nav. Inst. II, 771; 1885, and 12, 616; 1886.

is a crystal ; it is impossible to explode either alone, so that they are both perfectly safe as regards transportation. In order to make use of the explosive, the crystals are placed in the nitric acid, where they dissolve rapidly with a slight reduction of temperature ; there is no chemical combination, but only a solution in this case ; the mixture is then ready for use, but cannot be exploded by any ordinary method ; for explosion it requires the use of a fulminating or detonating fuse twice as powerful as that used to explode dynamite. If, by any chance, after being thus prepared, the mixture is not required for immediate use, the addition of a little water dilutes the nitric acid to such an extent that the other ingredient is no longer held in solution ; the crystals re-form, and can be separated by merely straining the mixture ; the crystals are then dried (without the slightest danger), and are ready to be used again ; the nitric acid is left in its diluted state and sold or used for other purposes. If the crystals are heated to a high degree of temperature, they burn, without explosion, somewhat like sealing-wax ; neither ingredient alone, nor the mixture, can be frozen at any temperature above zero Fahrenheit. Neither the crystals nor the mixture produce any other unpleasant effects on the persons who handle them except the usual effect produced by nitric acid. The nitric acid is strong, but not fuming, yellow in color, and very pure.

The crystalline ingredient of this new explosive is Mr. Gruson's secret. It is a substance well known, to whose transportation there is no objection ; it is, in fact, often transported to-day in commerce ; it is not soluble in water, does not absorb water, and never becomes damp. Mr. Gruson discovered this explosive while experimenting to find some economical method for breaking up his old-iron chills. He thinks he has such facilities for its manufacture as will allow him to make it cheaper than other people.

In order to allow the use of this explosive within projectiles, Mr. Gruson manufactures two varieties of shells, each containing two compartments connected by a truncated conical opening, this opening being ordinarily filled by a solid conical plug. The liquid nitric acid is placed in the cavity on the side of the larger base of this conical plug, the cavity being lined with glass ; the crystalline ingredient is placed in the other cavity on the side of the smaller base of the conical plug. If the shell is desired to explode when the shot strikes, the shell is made to contain at its forward end a percussion fuse opening into the first cavity containing the crystalline powder ;

the conical opening above described connects this first cavity to the second cavity containing the nitric acid within its thin glass case, the conical opening being so placed that its plug has its larger base toward the rear of the projectile. When the gun is fired, inertia forces the conical plug out from its cavity into the compartment containing the nitric acid, and the two compartments of the explosives are mixed thoroughly by the rotation of the shell during its flight. The explosive is then ready to be exploded by the percussion fuse at the moment that the shot strikes any resisting object. In other shells, where it is desired that the shot should explode at a certain time after striking, the shot contains at its rear a chemical fuse connecting with the cavity containing the crystalline powder ; in front of this latter is the compartment containing the nitric acid within its glass envelope ; the conical opening connecting the two compartments is placed with the larger base of the conical plug turned toward the front, so that the plug cannot be disturbed from its position by any sudden forward movement of the projectile. When the shot strikes, the plug and the crystalline powder in its rear are driven by their inertia into the nitric acid ; the whole is thus thoroughly mixed ; the time chemical fuse, broken by the shock of striking, will cause the explosion of the whole mixture at the end of any given desired interval thereafter. In the latest model of these explosive shells, the glass case containing the nitric acid is cemented to the interior of another case of thin wrought iron. The latter can be introduced within the projectile when desired.

The percussion shells have been fired at long ranges, so as to land in ordinary hard ground. The explosion was so violent that the pieces of the shell flew rapidly in all directions, backward almost as far as forward, thus showing the intensity of the explosion. Such shells, exploding behind the interior crest of a parapet, would destroy material behind this parapet and would injure men who might consider themselves secure because they were sheltered from direct fire.

This explosive has been tested by blows from a pile-driver, in order to see how liable it is to explode under percussion. A weight of 112 kilograms (246 pounds) falling one metre broke the case of the fuse without producing explosion ; falling three metres, it still failed to produce explosion.

Two examples may be quoted to show the strength of the explosion : First, a chilled-iron cylinder of 30 inches diameter was torn all to pieces by the powder which filled an 0.8-inch hole along its axis.

Second, one kilogram of the explosive was placed in a cast-iron shell of 75 pounds weight and exploded; the explosion tore the shell all to pieces in such a way that 240 of its fragments weighed in all only 37 pounds; the rest of the fragments were not to be found.

On the 29th November, 1881, the writer witnessed some experiments with this new explosive. The solid component looked like brown sugar, except that the crystals were needle-like, and nearly an eighth of an inch in length. When these crystals were placed in the flame of a Bunsen burner, they burnt slowly, in much the same way as sugar or sealing-wax, and with a good deal of smoke. Some of the crystals were put on an anvil and hammered without explosion. The crystals were then put into strong, but not fuming, nitric acid and were immediately dissolved. A few drops of the solution were put on the anvil and hammered without exploding. A piece of paper dipped in the solution was put in the flame of a Bunsen burner and burned in about the same way as the crystals had burned. A piece of paper put into the solution so as to serve as a wick was then ignited, and burned with increased flame, but without igniting the solution. Water was then poured into the solution, and the solid component recrystallized into white, flaky crystals. This recrystallization was accompanied by a slight *reduction* in temperature, hardly sufficient to be noticeable to the touch. Some of the explosive mixture was then placed in a thin metal tube in the ground outside the building and exploded by the use of a friction primer of triple the strength ordinarily used for exploding dynamite; the explosion produced a very effective result. The brown crystals were said to be poisonous if eaten, but not poisonous to produce any bad effects if simply tasted or handled. An actual test showed the writer that they were slightly astringent, with something of the taste of quinine.

Captain Piorkowski, Mr. Gruson's representative, was at Berlin on the 18th of November, 1881. On his return, he stated that the Prussian Government were going to continue experiments with the new Gruson explosive at Graudentz. The explosive does not yet work regularly enough, as it explodes sometimes one second only, and sometimes as much as ten seconds after impact. Mr. Gruson would like to have some other government besides Prussia experiment with this explosive, especially some government that would be willing to publish the results of its tests. He would not be willing, however, to make known the composition of the explosive unless in some way he could be first guaranteed a royalty or other compensation for the

use of the powder, if it should prove to be what he claims for it. For a similar reason he is not willing to furnish a sample of the crystalline powder, because it might be analyzed and the secret of the explosive discovered. He would be willing to send an agent to the United States or any foreign country to exhibit the explosive, in case that there was any possibility of selling the explosive, or obtaining a royalty for its use. He would be willing to sell anybody the use of this powder, and the right to manufacture it, but only in consideration of a cash sum payable immediately, or a royalty during a term of about 15 years. He estimates that the strength of this explosive is 1.3 times as powerful as nitroglycerine, and that the cost would be about 25 cents a pound, or less.

Another explosive, tested in France, has been brought to the writer's notice. This explosive is the invention of M. Michalowski, and is called "miner's powder." It is powerful, easily made, easily and safely handled and transported, and is well adapted to many military operations. This powder was lately investigated by the Society of Mineral Industry at Saint Etienne, France.* As a result of a series of experiments, the committee reported, in substance, as follows:

According to the wording of the patent the composition of the powder is:

Potassium chlorate,	50
Binoxide of manganese,	5
Organic matter, finely pulverized,	45
	<hr/>
	100

The organic matter which forms the combustible element of the explosive mass should be wood sawdust, powdered tan, bran, etc.

The committee concluded their report as follows:

1. That the miner's powder was manufactured without danger, in the most simple manner; it was only required to add bran to a solution of chlorate of potash and leave it to dry.

2. That its transportation should be attended with no difficulties, for it was only after some effort that the particles were exploded upon an anvil.

3. That the force of the powder is practically equal to dynamite No. 1.

* Engineering News, 90, Feb. 23, 1884.

4. That the gases produced by its explosion are probably much less injurious than those emanating from other explosives.
5. That this powder can be firmly compressed by rammers without danger, provided no sparks are evolved.

Still a third of these safe but violent explosives, available for many military operations, "ammonia-nitrate powder," has been brought to the writer's notice. In this explosive, ammonium nitrate forms the principal ingredient. This explosive was not tested in the writer's presence, but was said to be as powerful as dynamite, to fuse, but not to burn, in the presence of a flame, and to be exploded with difficulty under the blow of a hammer. This powder is said to be composed of:

Ammonium nitrate,	80
Potassium chlorate,	5
Nitro-glucose,	10
Coal tar,	5
	<hr/>
	100

The explosion of this powder requires the use of a 10-grain fulminating cap.

Captain Bixby also states that the French Government have been experimenting with the use of celluloid for a waterproof covering of powder-cases. A rough wooden box was painted inside with one coating of celluloid. It was then filled with nitric acid and left for 24 hours. When then examined, the wood was found to be entirely untouched by the nitric acid. It is thought that the celluloid will prove so excellent a waterproofing for powder-cans and cases, that there will be no further trouble in keeping powder dry, even in the dampest localities.

He notes also the method for covering floors and other surfaces of magazines with "cork paint" as practised in England, and describes Cohausen's psychroscope for determining the relative hygrometric conditions of the external and internal atmospheres of the magazine.

The *Scientific American*, 56, 101, Feb. 12, 1887, reprints from *Industries* an article entitled "Recent Progress in the Manufacture of Explosives," in which it says: "The various explosives now manufactured and known under the names of dynamite, sebastine, extra dynamite, petrolite, nitrolite, and possibly many others, consist of

nitroglycerine mixed with different proportions of solid materials, such as charcoal, gun-cotton, nitrate of potash, and different kinds of porous earth and clay. All these compounds have given rise to numerous accidents by reason of their spontaneously explosive nature. Many other nitro-compounds besides nitroglycerine have been suggested as explosive agents. Among these may be mentioned nitro-benzole, nitro-toluol, nitro-naphthaline, nitro-phenol, nitro-mannite, and the compounds obtained from starch, cellulose and sugar by the action of concentrated nitric acid.

"A German patent (No. 36,872) of Alfred Nobel, in Paris, covers the use of a mixture of metallic salts of acids rich in oxygen, *e. g.* nitrate, chlorate, or perchlorate, with one of the nitro-compounds of glycerine, sugar or cellulose. The barium, potassium and sodium salts are mentioned in the patent, and for blasting operations a mixture of from 75 to 80 per cent. of one of these salts, with 20 or 25 per cent. of nitroglycerine, is recommended. For firearms, 5 to 15 per cent. of nitroglycerine is added, or 10 to 30 per cent. of either nitroglycerine thickened with nitro-cellulose, or nitro-sugar, or nitro-cellulose alone, is substituted. These mixtures are said to be safe, and not liable to spontaneous combustion or explosion.

"A somewhat similar mixture has been patented by Jacob Engels, of Kalk, near Deutz (Nos. 36,705 and 10,232), in which the nitrate, sulphate, or chloride of ammonium is the salt added to the nitro-compounds. The composition of these explosives is somewhat complicated. They contain 5 to 10 per cent. pyroxyline, 70 to 60 nitroglycerine, 15.5 to 18 pyro-papier, 0.5 nitro-starch, 5 to 1 nitro-mannite, 0.5 nitro-benzole, 10 to 30 ammonium salts, 0.5 water-glass, and 8 to 10 of saltpetre. An explosive based on the same principle, and recommended for shells, is made from gun-cotton saturated with a solution of potassium chlorate (100 parts gun-cotton to 12 parts potassium chlorate), and then slowly dried at a temperature of from 62° C. to 75° C.

"The shells are filled with this compound by first making it into a paste with collodion (12 to 14 per cent.) and then allowing the mass to harden in the shell. This mixture is also said to be capable of withstanding a sudden shock without explosion. The double picrate of sodium and lead or barium obtained by mixing three equivalents of sodium picrate with one of lead or barium picrate is also the subject of another patent. The explosives in which these picrates are used have the composition: 15 to 30 per cent. barium sodium picrate,

8 to 30 lead sodium picrate, 2 to 10 potassium picrate, 20 to 5 nitronaphthaline, 40 to 20 potassium nitrate, 3 to $1\frac{1}{2}$ sugar, 3 to 2 gum, and 4 to $\frac{1}{2}$ of lampblack (English patent 14,140).

“M. Carl Lamm, the director of the manufactory of explosives at Stockholm, has come to the conclusion that one of the safest explosives consists of a mixture of nitrate of ammonium with a di- or trinitrobenzine. The dinitrobenzines are easily obtained from benzine by direct nitration with a mixture of nitric and sulphuric acids. All three compounds are thus formed, the meta compound being in the largest quantity. They are all soluble in alcohol, from which solution, on cooling, the meta compound crystallizes out first, while the ortho- and para-dinitrobenzoles remain in the solution. The meta compound melts at 90° , and, when free from nitric acid, can be kept unchanged for any length of time. The trinitro compound is easily obtained from the meta compound by heating it with more nitric acid and fuming sulphuric acid to 140° C. Numerous experiments have been conducted by M. Lamm with a view to ascertaining the best proportions of these two substances to yield the maximum explosive effect. He has named this mixture ‘bellite,’ and recommends its use as a substitute for the coarser kinds of gunpowder used in the larger firearms.

“Bellite has the important quality of not being spontaneously explosive; it can, therefore, be manipulated and transported without any risk. To cause it to explode, it is necessary to bring it into contact with a flame or with some substance that is strongly heated. Numerous experiments have been tried in order to determine whether it is possible to explode it by a violent shock; but in the two years during which these experiments have been carried on it has never been made to explode by a shock alone, or by friction. Both dinitrobenzine and ammonium nitrate are stable compounds, if in their preparation care be taken that there remains no excess of free nitric acid. P. J. Cleve, the well-known professor of chemistry in the Swedish University at Upsala, has confirmed these statements of the discoverer, and has certified that bellite may be stored, or transported by railway, without any danger of spontaneous explosion.

“Bellite appears to have a power which is greater than that of any of the explosives at present employed. In one experiment 15 grams exploded by means of an ordinary fulminating cap, projected a shell weighing 42.5 kilos. to a distance of 120 metres; and in experiments in blasting, bellite has been found to remove a greater quantity of

rock than that obtained by employing the same weight of explosives derived from nitroglycerine. The mean force of bellite is equal to thirty-five times that of ordinary cannon powder.

“The Swedish artillery have made a series of experiments with this new explosive that go to prove that when it is used for grenades, these grenades are not liable to spontaneous explosion by any sudden shock, and that when thrown and caused to explode by a convenient percussion fuse, the results are superior to those obtained from grenades charged in the ordinary way with powder. Mines constructed with bellite are not set on fire or exploded even when struck by a bullet.

“The explosive force of bellite, compared with that of fulminating cotton, is as 115 to 100. From these results it would appear that bellite marks a new departure in the history of the manufacture of explosive materials; and it would appear that from its valuable property of being incapable of explosion by shock or friction, we may not fear its application to the destruction of property in the same way that dynamite has unfortunately been used. M. Henry D’Estrey has lately brought this compound under the notice of the scientific public of France, so that we may hope that before long it may come into general use as a substitute for dynamite and the allied nitroglycerine compounds.

“Recent experiments by the Minister of War at Berlin on new explosive materials have just been conducted at the island of Eiswerder, near Spandau, and if this compound has been included in their investigations, we may hope for further particulars of its properties in the report on the results.”

The *Rev. Mar. et Col.* 91, 589; 1886, states that M. Ruckstchell, a Russian engineer, has invented a new explosive which he calls Silotvaar. From experiments made at Camp Krasnoie Silo, near St. Petersburg, the new powder possesses a penetrative force ten times superior to that of ordinary cannon powder. Its explosion produces neither fumes nor smoke, and is not attended with any detonation. It is said, too, that a motive force can be produced from this explosive and operated by a motor invented by M. Ruckstchell which is superior to gas or vapor.

The London *Telegraph* announces the discovery of a substitute for gunpowder, primarily intended to replace the gunpowder used on

the stage. The accidents which have happened to actors from the discharge of firearms are so frequent that any means of preventing them would be a boon to the profession. M. Edouard Phillippe, the inventor, showed the adaptability of his invention to the chassepot, the *fusil gras*, to old musketoons, revolvers, and for toy pistols made of wood. The explosive, fired at six paces, left no trace on a sheet of white paper; whereas the plug from an ordinary stage musket left at that distance an ugly black mark. The substance used by M. Phillippe consists chiefly of phosphorus, and, the cartridge being exceedingly thin, the whole charge completely disappears. No trace of it is to be found. The detonation, on the other hand, is as loud as that produced by gunpowder, the flame as vivid and the smoke apparently as dense, but it has the advantage of having no smell.

Appleton's Annual Cyclopædia for 1885, 342-347, contains a well-edited article on "Explosives," by Marcus Benjamin, Ph. B.

"Notes on Experiments with High Explosives," by M. M. Macomb, 1st Lieutenant 4th Artillery, U. S. Artillery School, 1886, is the title of a work of some 17 pages, with plates, which contains a detailed account of upwards of 50 experiments in which dynamite, atlas powder, forcite, explosive gelatine, rackarock and tonite were employed in destroying structures, disabling guns and gun-carriages, and breaching fortifications. There is nothing new either in the experiments or the results (though it is always wise to place such results on record), but, if this represents the course of instruction at the Artillery School, it is an eminently practical and useful course.

The *Professional Papers of the Engineer School of Application, U. S. A.*, 2, 1-121; 1885(?), contains a translation of the "Report upon Trials with Submarine Mines Executed Jointly by Sweden, Norway and Denmark, 1874-1876," made by C. W. E. Oxholm, C. E., Asst. Eng. Willet's Point. This translation is somewhat fuller than that published in *Proc. Nav. Inst.* 7, 121-154; 1881.

E. Bernard et Cie., of Paris, have published "Les Explosifs modernes," by Paul F. Chalon, one volume, 420 pp., with 161 figures. Spineux et Cie., of Brussels, announce the second edition of "Matériel de Guerre de nos Jours," by N. Adtz. The *Bibliotheca Historico-Naturalis* notices "La Poudre à Canon," by M. Hélène, Paris, 1886.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

JUNE, 1887.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XIV.

Under the title of "A Remarkable Explosion," Prof. L. R. F. Griffin describes, in the *Popular Science Monthly*, 30, 810-814; April, 1887, the circumstances attending the explosion by a stroke of lightning of one of Laflin and Rand's magazines at Brighton, Ill., August 29, 1886. The magazine was one of a group of eleven, standing on a comparatively open area of some forty acres, and it contained at the time of the explosion fifty tons of black powder and fifteen tons of dynamite.

The shock of the explosion was felt in Chicago, seven miles distant, as a sudden jar followed by a dull thud like that produced by a distant gun of large size. It was sufficiently violent to shake buildings six miles distant, so that, although a very severe thunderstorm was occurring at the time, guests in some of the hotels rushed frantically down-stairs, suspecting an earthquake. Plaster fell in the Immanuel Church, more than five miles away, so that it was at first supposed to have been struck by lightning, and a large plate-glass window in the Board of Trade building, about seven miles distant, was cracked, and the clock on its tower was put back three seconds. Examination of the locality of the explosion showed that the brick walls of the magazine had been pulverized and scattered over a wide area; the limestone foundation was torn up and a large part of the material

*As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address Torpedo Station, Newport, R. I.

broken into small pieces, the most of it carried through the air from forty to eighty rods ; and a hole was torn in the ground, there mainly tough clay, about one hundred and fifty feet long, forty feet wide, and from ten to twenty feet deep. All the buildings in the immediate vicinity were demolished, while those which stood within reach of the flying stones were more or less riddled. The loss of life was very small considering the extent of the damage, only one person having been killed outright, although several others were severely injured, of whom some have since died.

Such are the primary facts of the explosion itself. An examination of the ground in the vicinity, and of many of the buildings ruined near by, together with others at considerable distance more or less injured, developed certain minor facts that bear upon the general subject of explosions. Especially do they seem to show that such explosions may produce an earth-wave which may do damage at great distances, the undulation of the ground displacing objects, cracking walls, and shattering glass, much like an earthquake in miniature. Sometimes this may possibly prove the source of the principal destruction.

Looking directly at the destruction itself, the results of the explosion appeared as follows: The buildings nearest the wrecked magazine were all crushed together, and, so far as could be determined from the ruins themselves, were pushed away bodily from the demolished building for a short distance, not more than one or two feet. This shows that the explosives instantly produced a very large volume of gas, which forced itself against the surrounding air and condensed it very quickly, until it gave way in the direction of the least resistance, which would necessarily be upward. This condition was confined to a small circle ; for, while such a condensation would produce a wave of air, the mass bodily displaced must be confined within comparatively narrow limits. Displacement would not appear beyond.

Fortunately, at Brighton, no other magazine stood within this area, so that the dynamite in the others was unaffected by the shock, while the rain prevented the fire from spreading by means of dry powder. Outside of this area there was a narrow ring or circular strip of ground, with a radius of not far from fifteen rods, where comparatively little injury was done. One or two magazines stood in this region, and they escaped almost without injury, only being slightly battered by flying stones. Here the air was not moved as a

mass either way. The changes of density to which it was subjected were of the nature of molecular movements rather than motion of any great mass of air. Beyond that area the movement of the air was toward the point of explosion. This was shown by the forcing of the glass outward in all of the more distant buildings, while the walls of at least one dwelling-house and of several of the magazines left standing were thrown down toward the wrecked magazine. Furthermore, the roof of one magazine was clearly lifted and allowed to drop, besides being riddled with stones. These phenomena pointed clearly to diminished pressure of the external air, produced by the explosion, as is noticed in a small way when any gun is fired. Since most of the magazines stood in this region, no blow was struck upon them, and there was nothing to explode the dynamite stored within, else the first explosion would have been followed by others in a series and the damage multiplied.

These phenomena, taken together, seem to indicate the following as the steps by which the destruction was produced, though they followed so quickly that only delicate instruments would have distinguished them: First, the lightning exploded some of the black powder. The blow produced by this explosion detonated (?) the dynamite, tearing up the ground to make the hole, and breaking the foundation stone into small pieces. Then the rest of the powder exploded, sending the fragments away in all directions.

It is very strange that, when the danger from lightning is so well known—one of the same group of magazines was exploded by lightning in 1880—no precautions are taken by the owners for protection. The magazines are low structures, some of them roofed with slate, others with thin metal, in all cases very light, that they may offer but little resistance in case of explosion. The total neglect of precautions against lightning indicates a disregard of the known laws of electricity, or else the mistaken notion that a lightning rod, by furnishing a good conductor, attracts the lightning, and thereby increases the danger in place of being a safe path for the current. When such buildings stand upon level ground, in open areas, they necessarily become the path of any descending flash. If the electricity goes through the building, it becomes a source of danger, because it is likely to meet sufficient resistance to raise the temperature above the igniting point of powder, and it must be carried completely around the powder to insure safety. A network of metal rods carried over the tops of those whose roofs are slated, and given a sufficient ground connection, would

be a complete protection; it would carry away all the electricity, usually silently. To protect those with metal roofs, nothing more would be required than wide strips of metal from the roof itself to the ground. Of course, in either case, great care must be taken to prevent scattering powder on the ground within reach of electricity as it leaves the conductors. The problem of protection in this case has sometimes been compared with that of the protection of tanks in which petroleum is stored. This is a complete misconception. Protection of powder magazines simply requires a proper conductor to carry off the electricity, silently if possible, but so completely as to allow no escape in case of a flash. There are no complicating conditions, such as petroleum tanks present. Nothing, either in the material itself or in the air around, makes that a better conductor than neighboring objects. But in the case of petroleum tanks, gases are constantly rising from the petroleum and escaping into the air around, and particularly directly above. They frequently rise many feet above the tank, and experience proves that the gas, or the mixture of air and gas, is a much better conductor than the air itself. So the tank is likely to become the path chosen by every descending flash, and the problem of protection is not simply to furnish a conductor from the top of the tank, but one that shall conduct the electricity from the top of the ascending gas, always an uncertain height. So far no plan has proved completely successful.

The phenomena show clearly that two sources of danger arising from such terrific explosions must be guarded against. The glass broken within the first two miles proved a rush of air toward the destroyed magazine. The sudden uprush of gas, the mass being very highly heated, caused a vacuum, and the subsequent cooling added to the effect. The air rushed toward the vacuum from all directions, and when it was contained in a confined space, as a closed room, it quickly broke the glass, shattering it into small fragments, which fell outward. But the force which did this work was spent within a comparatively narrow area. Beyond that it only appeared as the back-and-forward movement of an ordinary sound-wave. The distance to which this was carried could not be determined, because beyond some seven or eight miles the report was not distinguished from the ordinary roll of the thunder.

This explosion produced an earth-wave as well as an air-wave. The force of the dynamite, exerted largely downward (?), not only tore the ground out to make a hole, but forced it away sidewise in all

directions. This formed a ridge around the hole, and at the same time it produced a wave, that is, an up-and-down movement of the earth. One observer, who was sitting quietly in a chair about six miles from the magazine at the time of the explosion, described the sensation which he felt as a quick movement down and up again. He was not quite positive which preceded, the motion upward or downward, but he thought that downward. That would indicate that the upward motion of the earth was first, since the human body has the sensation of moving in the opposite direction to the motion of the wave, and that agrees with the appearance of the hole. This earth-wave made dishes rattle in all places where it was felt perceptibly. In the central part of Chicago many plate-glass windows were cracked. These were injured by the earth-wave, not by the air-wave. They were simply shattered from the motion of the surrounding walls, but were not forced either inward or outward. One observer stated that a pane of glass near him was cracked at the moment when he felt the shock, not when he heard the report, which was a little later. This showed that the earth-wave moved faster than the air-wave which produced the sound. There is also reason to believe that this earth-wave travelled much farther than the air-wave. A self-recording barometer in the laboratory of Lake Forest University, about thirty miles distant from Brighton village, showed a sudden movement of the mercury at about that time, which could be accounted for only by referring it to the wave of the explosion. Probably this was not the limit of the movement. Unfortunately, there was no means of determining the rate at which this earth-wave moved. All these conditions combine to surround this remarkable explosion with peculiar interest.

The *Boston Herald* of June 6, 1887, gives an account of a new projectile, known as the Fannon-Winslow shell, which has been perfected by Massachusetts inventors. The idea of the inventor is to place three bottles containing the components of nitroglycerine in the interior of the shell, so arranged that they will crush and their contents mix when the shell strikes any object. Very powerful results are said to have been produced with this projectile.

A report of the trial of the Winslow shell by a board of ordnance officers will be found in the *Report of the Chief of Ordnance U. S. A., Appendix* 15, pp. 103-104, 1885. They describe the projectile as

being formed, like a Butler shell, with an appendage resembling a cascabel. The neck of the appendage, to which a wrench is fitted, is hexagonal. The part corresponding to the knob is a cylinder terminating in a spherical segment. The projectile is divided into two sections. The anterior part is a cylinder with an ogival head, and contains a cavity in which the ingredients to produce an explosive compound are contained. This section terminates at the rear end in a screwed tenon, by means of which it is fastened to the rear section. The rear section is provided with a cavity intended to receive a cast-iron plunger and a charge of rifle powder. Near the base of the projectile is a circumferential groove in which time-fuse composition is driven. This groove is connected with the rifle powder in rear of the plunger. An axial chamber is bored in the plunger and contains a small charge of rifle powder. The rear of this chamber is closed by a screw-plug, containing a vent filled with slow-burning composition.

The materials used for producing an explosive compound are glycerine and concentrated nitric and sulphuric acids. One pint of sulphuric acid and three quarts of glycerine were mixed in one vessel, and three pints of sulphuric acid and two quarts of nitric acid were mixed in another. A portion of the first mixture was placed in a glass jar, while a small jar placed within the first was filled with a portion of the second mixture. The liquid contents of the inner jar and of the outer jar when the inner one is inserted are equal in quantity, hence the proportions of the liquids are: sulphuric acid 2, nitric acid 2, and glycerine 1. The usual proportions, when nitroglycerine is manufactured by the ordinary processes, are about as follows: sulphuric acid 6, nitric acid 3, glycerine 1.

The jars are fastened together by screw-caps, and are placed within a tin cylinder, open at both ends, which fits the shell cavity. Stout cross-bars traverse the open end of the cylinder, and the exterior glass vessel is fastened to the bars by strong bands, which, aided by rubber straps, are designed to prevent the rupture of the jar when the piece is fired. The rupture is intended to be effected in the following manner: The time-fuse is cut at any point, and when the projectile has traversed a certain portion of its trajectory, the charge of rifle powder in the rear of the plunger is fired and the plunger is forced violently forward. This breaks the bottles, and, in connection with the rotation of the shell and the broken fragments, causes an intimate mixture of the glycerine and the acids, resulting in the form-

ation of an explosive compound. When the projectile strikes a resisting object, the shock of impact should (according to the report) cause the explosion of the compound thus formed, or, if this does not occur, then the charge contained in the axial chamber of the plunger will bring about the explosion.

The trial commenced April 23, 1885, when a shell was fired over water from an 8-inch muzzle-loading rifle with 35 pounds of powder. It could not be ascertained whether or not an explosion had taken place, for from the fragments that struck near the gun it appeared probable that the projectile had been broken up by the shock of the discharge. A second round was fired over land with 30 pounds of powder, the fuse being set at five seconds. The shell burst in the air in two and one-half seconds, and from the peculiar appearance of the smoke the rupture was regarded as due to the explosion of a substitution (?) compound. In the third round, fired with a 30-pound charge, over water, no explosion took place. The fourth projectile was exploded by means of an electric primer in an inclosure. The shell broke at the screw-thread into two pieces, the head being thrown some 25 feet out of the inclosure. The bottom was forced against the side of the inclosure.

In conclusion the board report that the acids can be safely transported to any point, the mixture can be effected without danger, and a shell arranged to contain them may be fired from a gun without injury to it. With the mixture used an explosive compound is probably formed, although the proportions of the ingredients used were not such as to give the best results. If they had been, and if the greatest possible amount of nitroglycerine producible by the ingredients which the shell cavity could contain were formed, it is not thought that the effect would be equal to that resulting with an ordinary bursting charge of gunpowder. The board therefore recommend that no further trials be carried on with this device or with devices closely resembling it in principle.

This same volume of the Reports of the Chief of Ordnance contains, on pages 57-59, a report of the tests of the 6-inch shells on the Snyder system* charged with dynamite. The board conclude that it is impracticable to fire shells containing commercial dynamite from a smooth-bore gun when a suitable powder charge is used under this

* Proc. Nav. Inst. 12, 617; 1886.

system, and although previous experiments by the board have indicated that explosive gelatin can be successfully fired from an 8-inch rifle with a charge of 40 pounds of powder,* and therefore could be safely employed in this case instead of commercial dynamite, yet they do not consider that any trial with it in this system would be of any value, because the projectile employed possesses little penetrative power, and, furthermore, the system is very complicated and expensive. The board does not recommend further experiments with it, since simpler and less costly methods promise greater and more valuable results.

On pages 79–80 of the above report is a description of “M. L. S. Buckner’s Aerial Drop for Explosives,” which is a method of using high explosives from balloons. The board state that the machine is ingenious, and there seems to be no doubt that it will work and drop its explosives at the fixed time to which the alarm-clock may be set. The machine has to be suspended from a balloon, and to be efficient would require a very accurate knowledge of the force and direction of the wind at different elevations, and, of course, at best could only be used under the most favorable circumstances, and when the wind was blowing in the direction of the object to be reached.

The *Army and Navy Register*, June 11, 1887, p. 380, states that Lieutenant J. W. Graydon (late U. S. N.) has devoted his attention to explosives, and has undertaken—

1. To charge ordinary shells with dynamite in such a way as to render it safe to fire such projectiles from heavy guns with service charges of powder.

2. To use dynamite and powder together in the charge, thereby obtaining an increased velocity without a corresponding increase of pressure in the chamber of the gun.

3. To produce a new explosive which shall be safer while at the same time very much more powerful than ordinary dynamite.

Last winter experiments were made at St. Petersburg with the shell filled with dynamite, and the projecting charges consisting of dynamite mixed with black powder. Four charges of the mixture of thirty-seven pounds each were fired from a 6-inch gun, Navy pattern, the shells containing 102 pounds of dynamite. The velocity was

* Report of 1884, Appendix 17.

1993 and the pressure 1736. Four service charges of thirty-eight pounds of powder, with 102 pounds of powder in the shell, gave a velocity of 1499 and pressure of 1724.

Graydon's method of charging shells was tested by a board of army officers at Presidio, Cal., in 1886. They reported, August 13: "We have witnessed the results of fifty-two shells filled with commercial dynamite fired with the service charge of powder from the 4½-inch siege gun, and they were all fired with perfect safety to the gun, with the exception of two, the results of which were lost on account of the fog. Every shell that struck the bank or cliff fired at (range 2200 yards) exploded by concussion, no fuse being required for the explosion. It is the opinion of the board that Mr. J. W. Graydon has solved the problem of firing shells with dynamite with perfect safety to the gun, and at the same time making explosion sure upon the impact of the projectile; and, pending a full and extended report upon the experiments, the board unanimously recommend that experiments be continued with the 8-inch rifle converted and the 15-inch smooth-bore."

Experiments on this method are to be made at Sandy Hook with the 100-pounder Parrott and 7-inch wrought-iron guns.

The *Revue d'Artillerie*, 30, 530-538; 1887, reprints from the *Militaire Spectator** of Breda an article on "The Use, in Germany, of Gun-Cotton for Charging Projectiles."

In 1883 Messrs. Von Förster and Wolff took out two patents—one for a process for preserving gun-cotton,† the other for the construction of a shell charged with this explosive. The process of preservation invented by Von Förster consists in plunging the gun-cotton, wet or dry, into ether for 15 to 20 seconds; there is formed on the surface a very thin, hard layer impermeable to water and of a yellowish-brown color, thus giving the gun-cotton the appearance of wood. Nitro-benzene or other liquid solvents of gun-cotton may be employed in place of the ether. This layer does not affect the explosive properties of the substance, but diminishes loss by flaking and cleavage, retards decomposition, maintains the humidity at nearly the desired point, and prevents the penetration of paraffine. However, this pellicle contains always some very small interstices through which

* Nos. 11 and 12, 1886, and Nos. 1 and 2, 1887.

† For a fuller account see Proc. Nav. Inst. 12, 563-602; 1886.

moisture may escape eventually, but this imperfection may be neglected if the gun-cotton is properly stored. Gun-cotton, not coated and containing 25 per cent of water, loses all its water in a few days if it be exposed in a brisk current of air, while the coated gun-cotton, exposed under the same circumstances, is not reduced to the dry state in as many weeks. Besides, the layer is so thin that its combustibility does not constitute a source of danger. In the case of dry gun-cotton for use as primers, after the treatment with ether, the detonator canal is plugged with paper and the disk is dipped in melted paraffine. This forms a second impermeable varnish.

The projectile described by the second patent is of cast iron formed of two parts which screw together, the interior being filled with disks of compressed gun-cotton. At the base of the shell is a fuse which fits into the perforations in the disks. The shell is provided with an ordinary percussion fuse, and this is connected with the primer by a fuse composition, which may be either gun-cotton in fine grains or a mixture of this body with meal powder, or some other nitro compound in fine grains, either alone or mixed with meal powder. The patent does not state how the fuse is held in place.

The arrangements described have been chosen as the result of experiments made at Walsrode on the effect of the explosion of gun-cotton in free air. These experiments of M. von Förster's led to the following conclusions: the power of gun-cotton increases with the density; in the moist state it is more *brisant* than when dry; it is advantageous to produce the inflammation of the charge at the part furthest removed from the object to be destroyed; and, finally, a cavity so placed as to follow the axis of the charge favors its action.

It does not appear that the shell described above has been experimented with, and later experiments on the explosion of gun-cotton in free air do not appear to confirm the conclusions reached relative to the position of the fuse and the existence of the central canal. They have, however, sought to utilize existing projectiles by devising means for charging them through the eye of the shell. These efforts have led to the taking out of another patent in May, 1885, for a method of charging and for a special mode of fixing the detonator.

The gun-cotton is used in the form of prismatic grains obtained by breaking up the compressed disks. They place 200 grams of dry gun-cotton upon the charge of wet gun-cotton. When the charge is in place they introduce a mandril through the eye of the shell, thus forming a canal in the cotton for the detonator and fuse, and they pour

into this space melted paraffine having a temperature of 75° to 80° C. This paraffine fills all the interstices between the grains, and in solidifying binds them into one compact mass. The fuse is similar to the German percussion fuse, model of 1873. The plug is elongated and opened at its lower end; it encloses a capsule containing one gram of fulminating mercury, and is surrounded by a band and tube, both of caoutchouc. The whole arrangement is held in place by a screw. If they wish to obtain a retarded effect they use a longer plug and interpose a fuse composition between the exploder and the detonator. In order to assure intimate contact between the fulminate and the charge they place a 10-grm. disk of dry gun-cotton around the detonator, and protect it from the action of shocks by caoutchouc bands.

The shells are charged before being stored in the magazine, but the detonators and fuses are put in place at the time of firing. A brass tube, destined to receive the detonator, protects the charge up to this time.

In the spring of 1885 the German Government furnished the Walsrode factory with a 15-cm. gun for the trial of this mode of charging. They used lead-covered shells of 2.5 cal. model of 1869, weighing 27 kg. and having a capacity of about 2 dm^3 . Each shell received a charge of 1.35 kilo. of gun-cotton, with 20 per cent of water in parallelopipedons 10 mm. on the side and 20 mm. long, and 200 grams of dry gun-cotton in cubical grains of 6 mm. on the side. They fired the charge of 1.5 kg. against a parapet situated at a distance of 70 m. The velocity, measured at 30 m. from the muzzle, was 245 m. Out of five projectiles no premature explosion was obtained. Two of them had been fitted with retarded fuses, and these produced deeper craters than the other three. The number of fragments was considerable, and their dimensions did not surpass some millimeters. A shower of fragments were thrown more than 70 m. to the rear.

They exploded a shell buried 1 m. in the earth and obtained a circular crater about 2 m. in diameter, 70 cm. deep, and of a capacity of 1.25 m^3 .

M. von Förster replaced this method adopted for holding the detonator by another, which is not described, but which seems to have given good results. He pursued these experiments and proved successively all the elements of the proposed system. For this purpose they fired an empty shell furnished with an unprimed fuse,

and with damp gun-cotton in the detonator, and they found that the fulminate in the capsule was not exploded. Then loaded shells containing neither fuse nor capsule were fired. There was no explosion and the gun-cotton was recovered unchanged. Next loaded shells, fused but not primed, were fired with a velocity of 420 m. against a parapet of wood, and afterwards of iron. There was no explosion, but as the resistance was increased the shells were broken up as if empty, and sometimes, though not always, the gun-cotton was set on fire.

Finally, he experimented with shell completely charged, fused and primed. More than 200 projectiles of 8.8 cm. were fired with a velocity of 450 m. The ordinary shells charged with gun-cotton were thrown from the rifled 15-cm. mortar with a velocity of 200 m., and from the 15-cm. gun with a velocity of 400 m. These last two pieces also projected steel shells of 6 calibers charged on the same system. There was no case of breaking up in the gun, and the final explosion was always complete.

In the experiments in breaking up at rest they have counted for a cast-iron 8.8-cm. shell weighing seven kilo., 200 fragments weighing over ten grams each, and 600 weighing from one to ten grams. An 8.8-cm. steel shell weighing 6.64 kilo. gave twenty-three large pieces weighing altogether 2.26 kilo., and 127 small fragments weighing together 2.865 kilo. A cast-iron shell of 15 cm. and 27 kilo. produced 376 pieces of more than ten grams, and 828 pieces of from one to ten grams. It was noticed that fragments weighing less than one gram traversed boards 25 mm. thick.

A projectile of 15 cm. and six cal., containing 9.935 kilo. of gun-cotton, buried vertically in the earth, the bottom being 25 cm. below the soil, produced a crater four meters in diameter and 1.3 meters deep, and having a crater of 7 m³. capacity. An eight kilo. petard gave a crater of 3.5 m. diameter, 1.5 m. deep and 6 m³. capacity; with a charge of sixteen kilo. they obtained a diameter of 5.1 m., depth 1.56 m., capacity 12 m³.

In November, 1885, the *Revista di Artigleria e Genio* announced that the German Government had adopted the Walsrode granulated gun-cotton for charging shells.

In 1882 the German artillery began on their side experiments on the use of gun-cotton for shells. These experiments were made primarily in order to determine the possibility of using large charges in projectiles for the 21-cm. mortar. For this they used cast-steel projectiles with thin walls, and they were five calibers in length.

According to an article in the *Militaire Spectator*, the torpedo shells for the 21-cm. mortar are made in two parts, a body and a head, screwed together. The charge is enclosed in a thin zinc or iron box, and is composed of disks of compressed gun-cotton 5 cm. thick and containing twenty per cent of water. The upper disk carries a cylindrical cavity which holds a primer of dry gun-cotton, and the latter is pierced with a detonator hole. When the charge is placed in the box a rod of wood is inserted in the detonator hole, and melted paraffine is poured in to fill the interstices between the disks. The box is closed with a metal cover pierced with a hole for the detonator. When the box is introduced into the shell the head of the latter is screwed on, and a hollow screw is inserted in the eye of the shell in order to hold the box in place, and at the last moment the fuse and detonator are inserted in the aperture in the screw. The use of disks admits of greater density of loading, the charge being about four times as great as when granulated gun-cotton is used; but, on the other hand, it requires that the projectile should be in two parts, and that special disks should be made for each caliber.

These projectiles have given good satisfaction, not only in the 21-cm. mortar, but also in the 15 cm. and the 28 cm. In the latter piece the shell is loaded with fifty kilo. (110 pounds) of gun-cotton.

The article is accompanied by valuable drawings, which cannot be reproduced here.

From the *Report of H. M. Inspectors of Explosives*, 1886, we draw the following account of two accidents which occurred in the manufacture of gun-cotton. In one of these cases an engine-fitter was heating a piece of cast iron which had originally formed the plunger of a hydraulic press, when an explosion occurred. The iron piston had a hole three-eighth inch diameter down the centre to within one-half inch of the face, when the hole narrowed to one-eighth inch, and it appears that a small quantity of unsuspected gun-cotton was present in the upper part of the hole.

The other accident was of a more interesting character. A workman was in the act of removing some gun-cotton from an acid centrifugal machine at Stowmarket, when it fired and burned his face. The accident was believed to have been due either to a drop of perspiration which may have fallen on to the gun-cotton, or more probably to the presence of a small quantity of oil, the oil can having been temporarily deposited on the cover of the machine, where some

of the gun-cotton may have come in contact with it. It was found on inquiry that two similar accidents had occurred previously at this factory, but had not been reported (as they should have been); and this led to inquiries being instituted as to the experience of the Government Gun-cotton Factory at Waltham. It appears that such accidents, viz. the "fuming off" of acid gun-cotton in or on removal from the centrifugals, were by no means uncommon, and these have been variously attributed to a drop of perspiration, to condensation of moisture either on the iron of the centrifugal or edge of the pot, or to the gun-cotton being wrung too dry, so to speak, and thereby becoming heated. The correspondence above referred to led to the institution, by the superintendent of the Royal Gunpowder Factory, of a number of experiments.

These experiments show very conclusively (*a*) that the presence of moisture or oil, even in minute quantities, is liable under certain conditions to produce ignition; (*b*) that such liability is sensibly diminished where mineral oils are used; and (*c*) that the liability varies to a very considerable extent with the temperature of the building.

It may be worth while to quote the following passage from a letter from Colonel Noble, Superintendent of Waltham Abbey, dated September 21, 1886, as bearing upon the subject:

"These accidents appear to occur much more frequently in hot than in cold weather. If the temperature of the air gets near 85° in the shade, the gun-cotton, after the acid has been wrung out in the machine, is very susceptible to ignition, and if a small drop of oil or a few drops of water get into it at this period it is almost certain to fume off. Instances have been known where the accident has been traced to drops of perspiration from the face of the man employed in emptying the centrifugal. You will see by experiments on the 8th and 13th September, that when the temperature was from 60° to 70° F., drops of water failed to ignite, but drops of oil or oil mixed with water never failed. One drop of oil was sufficient. On the 13th, while I was in the house, one of the centrifugals accidentally fumed off, igniting the gun-cotton in the machine next to it. The comparative frequency of these accidents at Waltham Abbey is mainly due to the very defective accommodation, which obliges the centrifugals to be worked in the same house in which the gun-cotton is purified by the boiling process."

"The Utilization of Waste Acids from the Manufacture of Gun-Cotton" is the title of an article by M. E. Allary, in the *Paint, Oil, and Drug Reporter*, 31, No. 13, p. 9; March 30, 1887.

In the course of an examination of the waste acids from the manufacture of gun-cotton he made a number of experiments with this liquid, with the object of again using the acid for the manufacture.

1. *Simple Distillation*.—The acid used had a density of 58° B., and was filtered through quartz to remove the suspended flakes of gun-cotton which it contained. 100 kilo. gave :

10.077 kilo. nitric acid of 50° B.

6.279 " " " " 10° B.

82.302 " colorless transparent sulphuric acid of 62 per cent.

1.342 " loss.

100.000

If the distillation is continued the 82.302 kilo. sulphuric acid of 62° B. will give 67.5 kilo. sulphuric acid of 66° B. The acids which were recovered in this way were of sufficient strength to be used again in the manufacture of gun-cotton; the nitric acid alone required a slight bleaching. By carefully conducting the distillation an acid of 48° B. can be directly obtained.

2. *Distillation over Saltpeter*.—Starting out on the assumption that, in the ordinary method of preparing nitric acid, the sulphuric acid might be replaced by the waste acids, and that on account of the increase of nitrogen oxides (the average quantity of which had been determined) a stronger acid could be directly obtained, he distilled these waste acids over Chili saltpeter, and obtained at once an acid of 48.45° B., and when the saltpeter was previously dried, even of 49.4° B. In addition to this he obtained an excess of yield, which must be ascribed to nitric acid contained in the waste acids.

An engineer in the Government powder works near Brest, where gun-cotton is manufactured, on obtaining information of these experiments, raised the objection that small quantities of gun-cotton might be present in these waste acids and give rise to explosions. Repeated experiments, made with large quantities of the waste acids, have, however, shown that after decanting and filtering there is no danger in the further treatment of these acids. (*Bull. Soc. Chim.*)

The *Sci. Am.* 56, 180; March 19, 1887, states that a number of experiments were conducted lately at the works of Messrs. Heenan and

Froude, Manchester, with a new explosive called "Roburite," which is manufactured in Germany, and is about to be introduced into this country for use in blasting operations. The composition and process of manufacture of this explosive are kept secret, but we understand that it consists of two non-explosive and perfectly harmless substances of such a nature that they may be stored or transported without special precautions or restrictions. These two substances may be mixed together when required, and, in combination, become roburite, a yellowish compound, which will bear rough handling with safety. We understand that an intense heat is necessary to explode it. In order to prove this, the explosive was placed, in the experiments in question, between two plates, which were freely rubbed together and hammered; and a small quantity thrown upon a fire was merely consumed, without exploding.

In order to obtain an idea of the explosive effectiveness of roburite, eight ounces of the explosive were placed in the centre of a plate of the very best steel and exploded. This plate was 3 feet square by half an inch thick, and a bulge of about 1 foot diameter and $3\frac{1}{2}$ inches deep was caused by the explosion. Twelve ounces of the explosive were then placed on a cast-iron plate, 6 inches thick, weighing nearly three tons. After the explosion the plate was found to be broken transversely. Unlike dynamite, roburite is said to be in no way affected by varying temperatures, and if duly protected against damp, it may be kept for years in any climate without its efficiency becoming in any way impaired. It is also claimed by the manufacturers that roburite has an explosive force greater than dynamite by at least 25 per cent.

In exploding, roburite does not produce noxious gases, and therefore may be used without intermission, while the poisonous gases given off by dynamite often necessitate the stoppage of work, in some cases for a considerable time. This new explosive is applicable for use in mines and quarries, and for torpedoes and blasting operations generally. (*Industries.*)

Under the title of "Unsuspected Dangers with Frictional Electricity in Blasting," W. E. Irich narrates, in the *Scientific American Supplement*, 23, 9172; January 1, 1887, an incident which occurred some years ago, and which nearly resulted in a most serious calamity, through want of knowledge regarding the power of induction.

About a week after the commencement of a long series of experi-

ments, several charges of gunpowder, gun-cotton, and dynamite were submerged in a river, about one hundred feet apart, the object being to learn what the effect of each would be when fired under the same conditions. The firing station and the position of the charges in the river were on this occasion totally obscured from each other, and about one mile apart. The cable employed to connect the charges with the firing apparatus consisted of a stranded copper wire well insulated with "Hooper's compound." Two lines were used for firing the charges, and a third or special cable of the same description was laid for communicating between the two points by telegraph. The three cables were laid on grassy land, parallel to but separated from each other by a space of a few inches throughout the greater part of their length. Electricity for firing the charges was obtained from Baron Von Ebner's ebonite-disk frictional machine.

The two ends of the cables at the river were each connected to a charge, while at the firing station one of the ends was carefully sealed and suspended in the centre of the firing room as a precaution and guard against the possibility of its coming in contact with the firing battery or machine. The other end was connected to the electric generator in connection with the charge to be fired first.

Final arrangements having been completed and all made ready, instructions were telegraphed to fire No. 1 charge, which was carefully and correctly done. Scarcely, however, had the firing key been depressed when word was wired from the river "to stop further operations, and leave everything at the firing station in the exact position it then occupied, as two charges had been fired instead of one only, as directed, and that in consequence a boat and a party of men engaged near the charge had most miraculously escaped being blown to pieces." This was declared by the operators at the firing station to be impossible through any action or neglect on their part.

The matter, however, was too serious to be left without a thorough and searching investigation. There was no question as to the second charge having been fired, and a careful examination of the cables between the points immediately after the occurrence failed to show the slightest sign of their having been tampered with. The evidence tended to locate the cause at the firing station, but how or by what means the charge was fired was quite unaccountable to all, and remained a matter of conjecture for several days, as the spare end of the cable had remained securely sealed and suspended, and was at the time of firing many feet away from the electric generator. A

very careful examination and insulation test of the end of this cable in the firing station proved that it had not been injured or tampered with in any way.

Experiments and investigation led eventually to the discovery of the fact that the firing of the second charge was due to induction. To remove all doubt of this, and for the information of all concerned, two half miles of the same description of cable were placed one foot apart throughout their entire length, fuses being connected to the cables at one end to represent the charges, and the wire being then grounded as before. To one of the cables at the firing station the frictional machine was connected, while the other end was carefully sealed and suspended in the same room as before, and at least ten feet away from the generator. The disks of the machine were given twenty revolutions, and the condenser was discharged, when both fuses fired. Other tests were then made, as given in the following table, to discover the greatest distance through which this inductive action would fire a charge, the wires being arranged as described above :

Distance of cable apart in feet.	No. of revolutions of the disk.	No. of charges fired.	Distance of cable apart in feet.	No. of revolutions of the disk.	No. of charges fired.
6	20	2	20	30	2
3	4	2	30	30	2
3	4	1	40	30	1
9	20	2	40	30	1
12	20	2	40	40	1
15	10	1	40	50	1
15	20	1	40	50	1
15	30	2	35	50	1
20	30	2	30	50	2
25	30	2	30	50	2

It would be dangerous on cables running parallel, and within forty or fifty feet of each other, to employ the frictional machine where more than one charge is connected.

It will be seen from the above table that a charge connected with a cable, one end of which was insulated, could be fired by the inductive action of another cable running parallel to and separated from it by a space of thirty feet when one class of electric generator was employed, whereas with a different generator the second fuse was not fired even when the cables were tied or twisted together, as will be shown by the following tests :

The frictional machine was now removed, and tests were made with dynamo machines and voltaic batteries, but in no instance was more than one charge fired, even when the wires were as close together as it was possible to get them, and then it was the one connected in circuit with the machine or battery.

These experiments clearly show that the detonation of the primary charge fired was not the cause of the second one exploding, and that the action was due to induction only. Had it been due to detonation, both charges would have been fired as readily by a dynamo machine or voltaic battery as with the static machine.

This power of induction could be put to good use, particularly in naval warfare, in firing and destroying the enemy's mines. It may also be interesting to note that, with a thirty-cell Grove battery and similar cable to the above, he succeeded in firing through a fault made by stripping off twenty-four inches of the insulation and submerging the bare wires in the sea. With an induction coil he failed to fire through a fault in the insulation only sufficient to expose the conductor to the eye. Wheatstone's magneto-exploder fired the charge through a leak one twenty-fourth of an inch long, but failed through a fault exposing one-eighth inch of the conductor. Siemens dynamo machine fired the charge through a leak exposing a surface of three-tenths inch, but failed to do so with a larger fault. Von Ebner's frictional machine fired through a leak of four and a half inches of bare conductor. It also fired the charge through a perfect break in the conductor. A four-cell Grove battery fired through three-eighth-inch leak, but failed to do so through three-quarters inch.

In connection with this it may be interesting to note that *Nature*, **17**, 50-53; 1877, in an article on "Modern Torpedo Warfare," in reviewing the results of some experiments undertaken in Denmark two or three years before, briefly says: "Another point was also noted. A current of electricity, if it emanates from a powerful frictional electric machine, traversing one of a bundle of wires, will induce a current in the other wires, and thus bring about the explosion of torpedoes other than that which the operator on shore desires to ignite."

We observe that it is not stated in either of these two cases whether or not experiments were made to prove that the insulation between the wires was perfect.

F. Raschig, *Annalen*, **230**, 212-221; 1885, accounts for the discordant results of the analyses of iodide of nitrogen by Gladstone, *Jour. Chem. Soc.* **34**, 1851, Stahlschmidt, *Pogg. Ann.* **119**, 421, and Bunsen, *Annalen*, **84**, 1, by the fact that the precipitate obtained by adding ammonia water to a solution of the iodide is decomposed by washing with water. Sesqui-iodamine, $\text{NH}_3\text{,NI}_3$ or $\text{NH}_2\text{I, NHI}_2$, is first precipitated, but it is converted during the process of washing into NHI_2 and NI_3 . The latter compound dissolves in potassium cyanide, forming cyanogen iodide: $\text{NI}_3 + 3\text{KCN} + 1\text{H}_2\text{O} = 3\text{CNI} + \text{NH}_3 + 3\text{KOH}$. The iodide of nitrogen prepared from a solution of iodine differs in its properties from the iodide obtained from the action of ammonia on finely divided iodine. The latter compound is much more explosive than the former, as it is capable of exploding when moist. The composition of this substance has not yet been ascertained.

By reference to the *American Chemical Journal*, **1**, 4-9; 1879, it will be found that J. W. Mallet has already gone over the ground which Raschig has been reviewing, that he has pointed out precisely the same source of error in the work of previous investigators, and that he has determined the composition of the amide produced by the action of ammonia on finely divided iodine and which was explosive under water, and he found that when it was produced with great care at a temperature below 0°C ., and by the use of the strongest ammonia water and well purified by washing with ether and alcohol, it had a composition corresponding to NI_3 or N_2I_6 , but with weaker ammonia hydrogen was found in the amide.

Mallet proposes to use the higher formula in view of the general fact that the compounds of nitrogen in which this element behaves as a pentad are those in which instability is chiefly observable, and from noticing the proportions in which hydrogen and iodine have been found in these amides it seems fairly probable that the molecules of these explosive compounds contain two pentad atoms.

T. Klobb, in studying "The Compounds of Ammonia with the Metallic Permanganates," *Compt. rend.* **103**, 384; Aug. 1886, finds that a permanganate of silver and ammonia ($\text{Ag}_2\text{Mn}_2\text{O}_8\cdot 4\text{NH}_3$) may be formed by dissolving one equivalent of potassium permanganate in water at 10°C ., saturating with cold ammonium hydroxide, and adding two equivalents of silver nitrate dissolved in ten times its

weight of water. A crystalline precipitate is formed at once which, when washed and dried, has the form of a violet powder, and is but little soluble in cold water, though more soluble in warm. It slowly decomposes on exposure, losing ammonia and leaving a solid residue. Heated brusquely it fuses and is decomposed. It detonates under the blow of a hammer.

The cobaltic dodecammonium permanganate $[\text{CO}_2](\text{NH}_3)_{12}(\text{Mn}_2\text{O}_8)_3$ is deposited as a black crystalline powder when concentrated solutions of one equivalent of luteocobaltic chloride and three equivalents of potassium permanganate are mixed. When dissolved in boiling water it crystallizes out on cooling in small brilliant black crystals having the form of cubes, octahedra, and modifications of these two. When these crystals are heated or struck they detonate.

As a result of further study of the "Diazo-compounds," P. Griess, *Berich. Berl. Chem. Ges.* **19**, 313-320; 1886, has succeeded in producing a number of triazo and tetrazo compounds. Among these is the metatetrazo benzene platinum chloride having the formula $\text{C}_6\text{H}_4.\text{N}_2(\text{NCl})_2.\text{PtCl}_4$. This crystallizes in very small roundish yellow plates, nearly insoluble in cold water and alcohol, but decomposed with evolution of nitrogen when heated with these liquids. The dry salt explodes violently when heated. The gold chloride $\text{C}_6\text{H}_4.\text{N}_2(\text{NCl})_2.2\text{AuCl}_3$ is obtained as an explosive precipitate consisting of microscopic yellow needles. These salts resemble the diazo compounds in their reactions.

R. Möhlau, *Berich. Berl. Chem. Ges.* **19**, 280-283; 1886, prepares "Nitrosophenol Hypochlorite" by dissolving 1 gram of nitrosophenol in 500 cc. of water, adding 5 cc. of hydrochloric acid, and then running in a solution of bleaching powder until a distinct odor of hypochlorous acid is observed. It crystallizes in slender yellow needles having the formula of $\text{C}_6\text{H}_4\text{NO}_2\text{Cl}$, explodes when quickly heated to about 70° , or when touched with a drop of strong sulphuric or nitric acid, and gives Liebermann's reaction. It reacts energetically with amines and phenols, is resolved into nitrosophenol and hypochlorous acid by alkalies, and when heated with dilute sulphuric acid is decomposed into quinone, hydroxylamine, and hypochlorous acid. Acetophenonoxime also unites with hypochlorous acid.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

OCTOBER, 1887.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XV.

“The Pneumatic Dynamite Torpedo Gun,”† which has been attracting so much attention for the past four years, is described and its good qualities set forth at length by E. L. Zalinski in the *Jour. Mil. Serv. Inst.* 8, 1-35; 1887. The first 2-inch gun was designed and constructed by Mr. Mefford, of Ohio, in 1883; the 4-inch by Geo. F. Reynolds, and the 8-inch by Nat. W. Pratt. To Lieutenant Zalinski belongs the credit of having given direction to the development of this gun so as to render it a practical military appliance, by indicating in a general way the requirements to make it such, and he has labored most zealously to this end. The electrical fuze is alone his personal invention, but it is one of the most valuable and successful features of the system. The projectile used is a modification of a form designed by Colonel John Hamilton.

The 8-inch gun has been worked with 1000 pounds pressure, and at an elevation of 35° , a shell carrying 60 pounds of explosive has attained a range of $2\frac{1}{4}$ miles, while one carrying 100 pounds has attained 3000 yards with 33° elevation. The change in pressure during firing may be corrected by changing the elevation or the “cut off.” Thus, in a recent trial, the initial pressure was 1000 pounds and the elevation 14° when, the “cut off” adjustment having been varied, the first round gave a loss of 47 pounds and a resulting

* As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. *Address Torpedo Station, Newport, R. I.*

† *Proc. Nav. Inst.* 11, 287-293; 767-769; 1885, and 12, 617; 1886.

range of 1816 yards, while the second round gave a loss of 68 pounds and a resulting range of 2492 yards. Range tables for introducing both variables are to be provided the gunners on a brass plate attached to the pressure gauge.

Lieutenant Zalinski claims for this gun great rapidity of fire. He believes that with trained men the gun may be fired at the rate of once each minute. In the trial before a U. S. Naval Board, in June, 1886, with untrained men and without great effort being made, five rounds were fired in nine minutes and forty seconds. This was with the old form of projectile, involving the placement of the gas check, etc. The accuracy of fire in these five rounds was also remarkable. The range was 1613 yards, the elevation $10^{\circ} 40'$, the pressure 1000 pounds, and the "cut off" set to produce a loss of 50 pounds. Four of them attained exactly the same range, the other having gone only seven yards beyond. The maximum lateral dispersion was equivalent to only 6.2 yards. The wind was quite variable, but no attempt was made to follow it except once, just after the first round.

A 2-inch rifle gun has now been built which is to be tested, even to the final bursting of the gun, to establish the limits to which rifling can be safely used. A torpedo cruiser to carry two $10\frac{1}{2}$ -inch and one $12\frac{1}{2}$ -inch gun is now building for the U. S. Government. The range of these guns will be at least one mile. The $10\frac{1}{2}$ -inch shell will carry 200 pounds of explosive gelatine, equivalent, according to Zalinski, to 326 pounds of dry gun-cotton. The $12\frac{1}{2}$ -inch will carry 400 pounds of explosive gelatine, equivalent to 652 pounds of dry gun-cotton.

In comparing the pneumatic gun with gunpowder guns, Lieutenant Zalinski says: "The feasibility of using gunpowder for the propulsion of shell charged with high explosives is continually broached. It has been frequently tried, but invariably with final disastrous results, where the experiments have been carried up to moderately *large* charges.* By large charges, I refer to shell charges not less than fifty pounds and reaching up to one thousand pounds, and even to shell charged with a ton of high explosives.

"The advocates, or rather the predictors, of the use of high explosives from powder guns also demand *penetration* before explosion. If *large* charges are to be thrown, the shell must necessarily be made thinner, and it is very doubtful if it will then withstand the concentrated blow it receives upon striking the target, so as to penetrate even a moderate thickness of armor. The battering shell of the 100-ton gun

* Proc. Nav. Inst. 13, 417; 1887.

contains a bursting charge of only twenty-five pounds of gunpowder. It would seem that the walls of the shell would have been made as thin as consistent with ability to perforate armor without breaking up.

“Assuming that twenty-five pounds of a high explosive could be substituted for the gunpowder, it is very doubtful if it could be carried through heavy armor successfully before explosion. There is no record of large battering shell fully charged with gunpowder having perforated armor over six inches in thickness, without explosion until perforation. On the contrary, explosion takes place prematurely, almost immediately upon impact, with the result of less injury to the target than that produced by an uncharged shell. Much more surely will this be the case if a high explosive be substituted for the gunpowder, as the bursting charge, unless the shell cavity is well cushioned. To do this involves reduction of explosive capacity. The energy available, after breaking up the very thick and tough walls of steel shell, will be but little greater than produced by the gunpowder. The effect as to the material injury or man-killing power will not much exceed that producible by the shell charged with gunpowder.

“In firing a shell from a powder gun, the walls of the shell must necessarily be sufficiently strong to withstand the initial shock. This limits somewhat the capacity for bursting charge, even when armor piercing is not sought for. If a high explosive is used, some cushioning device is requisite, and a further reduction of capacity ensues.

“Assuming that a shell charged with some of the high explosives can be thrown with safety from a powder gun under normal conditions of pressure, it is known that abnormal pressures, varying therefrom as much as 5000 to 12,000 pounds per square inch, are not infrequent. This may be looked for especially when the gun is warmed by continuous firing. In addition to this, the shell and the contained charge may become warmed by remaining in the hot gun bore some little time before being fired. The high explosives increase very rapidly in sensitiveness by slight increments of heat. If, then, with this condition of increased sensitiveness we have in addition an abnormal pressure, a premature explosion is very likely to occur. Much more will this be the case when the bursting charge is one of the high explosives. In this connection another matter is to be considered. It is well known that the high explosives are capable of producing more or less violent explosions, depending

upon the character of the initial shock or detonation. The more insensitive the explosive the more powerful must be the detonating charge to produce an explosion of the first order. Fulminate of mercury appears to be requisite in all cases. But fulminate of mercury is even more sensitive to shock than either ordinary dynamite or dry gun-cotton; hence the resulting shock must be tempered so as not to explode the more sensitive *detonating* charge rather than the specially insensitive *bursting* charge. Wet gun-cotton has been substituted for powder charges, but being quite wet reduces its explosive ability nearly to par with gunpowder. Particularly is this the case where no detonating charge is used of dry gun-cotton and fulminate of mercury. Where the explosion takes place by simple impact, not alone is it of a low order, but, as the initial point of explosion is from the front, the resulting injury to the target is less than from a blank shell." The author quotes Commander Folger, U. S. N., in support of these latter views.

In discussing the effect of tamping the author says: "A cartridge of 8 ounces of dynamite was suspended in superficial contact with an iron plate three-quarters of an inch thick and there exploded. The result was a simple indentation of the plate. A charge of 8 ounces was again suspended against the plate, but over it was loosely suspended a piece of angle iron open at both ends and of such size that the inscribed circle between its sides and the plate was less than the cross section of the charge, which was cylindrical. Thus there was no direct pressure against the cartridge, yet a large elliptical hole was blown through the plate considerably longer and broader than the cartridge. This experiment was repeated with almost identical results; when both plates were placed together a hole was blown through *both* plates."

Again: "Comparisons are frequently made as between the high-angle fire of the pneumatic gun and the flatter trajectory of high-power powder guns. The comparisons are persistently made, notwithstanding the fact that it should be considered more as a torpedo-projecting machine than as a gun, and that the comparison should be made with torpedoes rather than guns. Nevertheless, even when considered as a gun, its high-angle fire is not altogether a detriment, and possesses important elements of efficiency as such, even when compared with high-power guns.

The experiences at the bombardment of Alexandria, and practice trials from English ships under the most favorable conditions, indicate

that the great accuracy of fire of high-power guns is in a measure neutralized by the unstable platform which the ship gives. From this it would appear that naval combats, instead of taking place at ranges of from 5 to 10 miles, will rarely begin at much more than one mile range, and the tendency will be to come to closer quarters. Two miles may be considered the longest ranges at which attack of fortifications will take place." Hence, both "will be at such ranges as to make it possible to bring into play the pneumatic gun."

"The high-power guns, with their relatively flat trajectories, will be thrown out as to range, more by slight changes of angle due to the unstable platform, than will the higher angle fire of the pneumatic gun. The change of range due to error of judgment as to proper instant of firing will be much greater with the high-power guns than with the pneumatic gun. The variations of the latter are more likely to come within the limits of error in judgment of distances.

Again, at the short range mentioned, the high-power guns have, owing to the flatness of their trajectory, only the vertical projection of the sides and turrets of the ship as the available target, and missing these, no result can follow. This portion of the target is most heavily armored. On the other hand, the torpedoes from the pneumatic gun have, primarily, the over-water hull of the vessel, involving both its deck, which is relatively large in area and weak in armoring, and the vertical target to which the high-power guns are limited. To this last, if the calibre of the gun is moderately large, serious injury may be done, directly and indirectly, while the deck, if struck, is sure to be crushed in.

But, in addition to the over-water hull, it has the very great chance of doing fatal injury to the under-water hull, if missing the direct hit of the target.

No small element, in considering the effectiveness of this weapon, will doubtless be the moral effect. The knowledge that escape is not assured when the enemy's missile has failed to make a direct hit, and that the danger may even be *enhanced* by that miss, will not have a reassuring effect on the crew of the vessel attacked."

The writer then considers the use of this weapon for coast defense, countermining, for defense of ships, and as an adjunct for ships in ramming, and for torpedo rams. The paper is illustrated with a number of cuts.

By direction of the Secretary of the Navy, a test of the pneumatic gun was made September 20, 1887, by anchoring the Silliman (a

condemned coast-survey schooner, 80 feet long by 20 feet beam) at a distance of 1980 yards from Fort Lafayette, and using her as a target. The projectiles contained 55 pounds of explosive gelatine each, and three of them were sufficient to completely wreck the vessel. A description of the trial may be found in the *Army and Navy Journal* or the *Register* for September 24, 1887. Instantaneous photographs of the appearance of the target after each shot occur in the *Scientific American*, October, 1887. Some delay having arisen during the experiments with the Silliman, additional experiments for rapidity in firing were, according to the *Army and Navy Journal*, October 8, 1887, made September 30. Ten shots were fired, each projectile being loaded with 55 pounds of sand, and weighing complete 140 pounds. Firing commenced at 10.42 A. M. and ended at 10.52.30, or about one shot a minute. In the next shot the projectile contained 100 pounds of sand, and it weighed filled 203 pounds. With an elevation of $32^{\circ}42'$ it had a range of over two miles and a half. Time of flight $24\frac{1}{2}$ seconds. Initial pressure of compressed air 975 pounds, final 825 pounds. Two similar projectiles, with an elevation of 15° , were fired with the gun sighted for 15 yards to left of target. The shots fell within 3 yards to left. The first projectile was 10 seconds in flight; initial pressure 750 pounds, final 625 pounds. The second was 9.04 seconds; initial pressure 750 pounds, final 615 pounds. Range 1772 yards. Of the time shell fired, two fell short 50 to 70 yards. Six would have hit a target the size of the Silliman, and two would have exploded sufficiently near to have injured her seriously. This was the first time that rapid firing with a large number of shell had been attempted, and the result indicated that a modification in the connections between the storage reservoirs and the gun was needed.

The experiments with this gun have given rise to considerable discussion. General Berdan gives his opinion of the value of the trial in the *Army and Navy Register*, October 8, 1887, to which Zalinski replies in the *New York Commercial Advertiser*, October 17, summarized in the *Army and Navy Register*, October 22. In the *New York Commercial Advertiser*, August 30, Zalinski also replies to the criticisms of General H. L. Abbot. In an interview in the *Washington Post*, October 16, Lieutenant John P. Finley, of the Signal Service, criticises the gun in the light of the dynamite experiments made at Sandy Hook, and points out how moisture on the hands or in the atmosphere may prematurely fire the electric fuze. The merits of the gun are strongly defended by Colonel John Hamilton, in the

Army and Naval Journal, October 29. This is but a minute part of the literature to which this invention has given rise.

Lieutenant C. A. L. Totten, U. S. A., proposes, in the *Army and Navy Journal*, July 23, 1887, that "Dynamite Archery" be resorted to, ships being armed with catapults, and *dynamite grenadiers* with crossbows from which arrows tipped with dynamite may be thrown.

Experiments in firing shells loaded with dynamite, by Mr. B. D. Stevens' method, were tried October 11, 1887, at the State Arsenal, Montpelier, Vt. The piece was a twelve-pound brass Napoleon; the shells were spherical, and the charge one-half pound of 35 per cent dynamite, a time fuze being used. The shells were fired with the usual service charge of two and a half pounds of powder. Five rounds were fired without any premature explosion. (*Army and Navy Register*, October 15; *Army and Navy Journal*, October 22, 1887.)

From the *Daily News*, Newport, R. I., October 24, 26 and 28, 1887, we learn that experiments have been made at the torpedo station to test the process proposed by Mr. Serge D. Smolianinoff for firing nitroglycerine with safety from gunpowder guns. His secret consists in rendering nitroglycerine perfectly insensitive to concussion or to detonation by heat, or by any means except by his patented burster. He further claims to be able to explode his shell at any point of the trajectory or after penetration.

The experiments consisted, after some preliminary trials, in firing shells filled with the mixture from service guns with two-pound charges of powder. Three filled shells, unfuzed, were fired at a stone wall forty-seven paces distant, without premature explosion. The remainder, fuzed, were fired up the bay. There was no premature explosion in the bore, and the shells exploded in mid air at a distance of about a mile, after about five seconds.

Mr. Smolianinoff had previously fired over 300 shells from a condemned 20-pound rifled Parrott, using an 8-inch conical shell completely filled with the prepared nitroglycerine, and a 3-pound charge of Dupont's F. F. powder, without having had a failure. The account of some of these earlier experiments will be found in the *Daily Alta*, San Francisco, Cal., June 13, 1887.

The *Illustrated Naval and Military Magazine*, 5, 402-412, December, 1886, contains a quite interesting paper on the use of "High

Explosives in Warfare"; meaning thereby their use as charges for projectiles from guns. The paper opens with a lengthy description of the pneumatic gun.* This is followed by an account of the experiments made by the U.S. War Department† with explosive gelatine, and finally the experiments in Germany, Italy, Switzerland, and elsewhere with gun-cotton, hellhofite,‡ romite, Parone's explosive, and nitrocolle. The paper is liberally illustrated with cuts of apparatus and projectiles, and of fortifications and the like, showing the effect of the explosions.

It is stated that romite is a solid, containing neither nitroglycerine, gun-cotton, nor any analogous compound. It can only be exploded in a closed vessel by means of a dynamite cap, but this may occur at the lowest temperature. It can be manufactured without an extensive plant and at an extremely cheap rate. Romite was invented by Mr. Sjöberg, a Swedish engineer, and has been tested in shells by the Swedish artillery. The results were considered satisfactory, but only small amounts were used.

Parone's explosive consists of two parts of potassium chlorate and one of carbon disulphide. From experiments in Italy with the 9-cm. and 15-cm. projectiles it was concluded that this mixture was an exceedingly safe one; that it would not explode without a fuze—not always a desirable quality—and that although its effects were not strikingly superior to those of powder, they increased rapidly with an increase of calibre. On the strength of this report the explosive was fired from a 24-cm. mortar at a range of 3000 m. The mortar burst at the first discharge. The commission recommended the separation of the two constituents of the mixture, but this plan does not seem to have worked well.

Nitrocolle is, according to the *Belgique Militaire*, a new explosive discovered in Belgium, which is as powerful as nitroglycerine, but much easier and cheaper to manufacture. To make it, strong glue is placed in cold water until it has absorbed the maximum quantity of the latter; the mixture is next solidified by means of nitric acid, and afterwards treated with a mixture of nitric and sulphuric acids, as in the preparation of nitroglycerine. The resulting substance is finally washed several times to remove the excess of acid.

In summing up the results of the Italian experiments executed with the Gruson shell, the *Rivista d'Artiglieria e Genio* considers that

* Proc. Nav. Inst. **11**, 287; 1885.

† Loc. cit. **13**, 411; 1887.

‡ Loc. cit. **11**, 771; 1885, and **13**, 240; 1887.

the Hellhoff's composition is a perfectly safe explosive, but that its power is by no means so great as had been expected.

In conclusion the writer says, although these experiments furnish few instances of full and complete success, we may infer that the future of high explosives is assured. It can now only be a question of time before the use of these agents in powder guns is rendered safe and effective.

An interesting series of experiments on Roburite* was carried out on June 14 at the School of Military Engineering, Chatham, under the superintendence of Major Sale, R. E. This explosive belongs to the Sprengel class, being a mixture of two substances, neither of which separately possesses explosive properties; in this case both components are solid, and the resulting mixture has a sandy, granular appearance, somewhat resembling the commonest yellow sugar. Roburite is the invention of Dr. Carl Roth, a German chemist, who claims for it the following advantages over other explosives:

1. That the two components are perfectly harmless and inert separately, so that they can be stored and transported without any restriction whatever.

2. That even when mixed or ground up together in ordinary coffee, cement, or flour mill, the mixture is perfectly safe to handle and use, as neither percussion, friction, nor the application of an ignited or heated body will cause it to explode; this can only be effected by using a detonator charged with fulminate of mercury.

3. That, when detonated, roburite produces neither spark nor flame, and will not therefore ignite either fire-damp or coal dust in mines. Dr. Roth states that this point was decided by the trials of the Imperial German Commission upon Accidents in Mines, and that in consequence this explosive is now being introduced into the coal mining regions of Germany, as affording absolute safety to the men employed.

4. The amount of noxious gases produced by its explosion is so infinitesimal that for this reason alone it is superior to other explosives in common use for deep mining work. The report from a mine in Westphalia, with shafts about 1500 feet deep, states with reference to roburite: "The men are not inconvenienced by the gases, and experience no difficulty whatever in breathing the moment after a shot has been fired, and they resume their labors at once."

* Proc. Nav. Inst. 13, 420; 1887.

5. Roburite is not subject to deterioration through climatic variations of temperature. It should be kept dry, but if it becomes damp, its strength can be safely restored by drying.

The object of the trials was to test roburite in comparison with gun-cotton, dynamite and blasting gelatin. The programme of the experiments actually carried out was as follows :

A. Safety Tests.—After being ground through a small hand mill, the substance was struck direct and glancing blows with heavy hammers upon iron plates, without any result. Flame was then applied to a portion of it by means of a short length of Bickford fuze, but without igniting the mass ; thrusting a red hot iron from a portable forge into the roburite caused only slow combustion and crepitation locally, which ceased when the iron was withdrawn. When a quantity was put on the forge fire it merely burned away like an ordinary combustible. Dr. Roth wished to fire a powder charge in contact with the roburite, but it was considered that the above named tests were more severe.

B. Tests on mild steel plates 2 ft. 6 in. by 2 ft. 6 in. and of various thicknesses. These plates were laid flat in shallow trenches, a hollow being left underneath the central portion of each plate ; heavy timber barks were stacked around each square trench, with the object of showing the comparative dispersive force of each explosive.

1. Three pounds each of dynamite and roburite were placed on the centre of plates 2 in. thick, some sandy loam being piled loosely on top. The results of detonation were that the dynamite produced a dent in centre of plate $1\frac{3}{4}$ in. deep ; the indentation produced by the roburite was about $1\frac{1}{2}$ in. deep, but the bulge appeared to have a wider area than in the former case.

2. Five pounds each of roburite and gun-cotton were then exploded upon the same plates, with the result that, in the former case, the plate was smashed into four tolerably equal pieces, while the gun-cotton made a breach through the centre of the plate somewhat resembling that which would be caused by the penetration of a large projectile. The diameter of the hole was roughly 12 in., with five radial fissures almost reaching the edges, the longest 15 in., the plate being at the same time bent into the shape of a pack saddle ; this would seem to have been a remarkably tough piece of metal. The timber barks were scattered in all directions.

3. Eight pounds each of dynamite and roburite were then detonated upon plates 3 in. thick. The dynamite caused an indentation

2½ in. in maximum depth, while the roburite gave a bulge 3 in. deep in the centre, and of a larger area, reaching apparently almost to the corners of the plate.

4. This series of tests was concluded by exploding 12 pounds each of roburite and gun-cotton on plates 4 in. thick, rather more loam being heaped on top of each. The roburite caused a wide indentation 1⅞ in. deep in centre, while the tremendous local force of the gun-cotton was exemplified in a striking manner. In addition to an indentation 3½ in. in greatest depth, a small crack appeared to extend right through the plate, this crack corresponding with one edge of the lowest slab of gun-cotton, the rectangular shape of which could be clearly seen indented on the steel plate, the depth being ¼ in. at the crack and ⅓ in. along the other edges of the slab. There is a circular hole drilled in the slab of wet gun-cotton to receive a small cylindrical disk of dry gun-cotton as a primer, and the position of this disk was marked by a circular hollow in the steel plate ½ in. deep in centre.

C. Blasting or Mining Test in Brick-work.—Three holes, each 1¼ in. in diameter and 18 in. in horizontal depth, were drilled in the solid brick-work of the counterscarp wall, and were respectively charged with 2 oz. of gun-cotton, blasting gelatin, and roburite; the holes were then tempered with loam in the ordinary manner, and fired by means of short lengths of Bickford fuze. The gun-cotton produced no apparent effect upon the brick-work, but Major Sale was of the opinion that the hole must have been open, or very weak, at the back. The blasting gelatin produced violent local action, displacing the brick through which the hole had been bored and the four adjacent to it. There was a slight bulge in the wall, the cracks extending radially from 10 in. to 12 in. The roburite exhibited a more widespread rending action upon the wall, the radius of disturbance being 15 in. or more, and the bulge being also greater. Rather larger charges of each explosive would have afforded a more satisfactory comparison.

D. Ground Mines.—Ten pounds each of gun-cotton, blasting gelatin, and roburite were loaded into holes in the bottom of the ditch 4 ft. deep by 8 in. in diameter, filled up with sand and slightly tamped. The explosion of these charges cast up tremendous fountains of loam and sand, and resulted in the following craters: Gun-cotton, 10 ft. 6 in. wide by 1 ft. 8½ in. deep; gelatin, 14 ft. 6 in. wide by 3 ft. 7 in. deep; roburite, 12 ft. 3 in. wide by 2 ft. 9 in. deep. The explosion of the gun-cotton mine appeared to cause great local action; but it will be

seen that the area and depth of its crater were considerably less than that caused by the roburite, which again must yield the palm in this instance to the blasting gelatin. It is, however, to be remarked that these mines had been placed much too close to one another, so that their craters crossed; this would give whatever charge was the last to explode a certain advantage.

In summing up the results of the foregoing experiments we must bear in mind the great difficulty—we had almost said the impossibility—of obtaining any absolute standard of comparison of the relative strengths of two or more explosives. Each will seem to prove itself superior for certain purposes. Judged, however, by any standard of comparison, it appears that the new explosive has acquitted itself very well, and, especially when we consider its absolute safety, must have a great future before it. Roburite has shown itself to be in some respects more powerful than dynamite, to which it is likely to prove a serious rival in the industrial field, although the latter has the proverbial advantage of strong possession of the ground. An important element in the struggle for ascendancy will be the price at which roburite can be supplied as compared with dynamite, and this will be, we understand, strongly in favor of the new substance.

As regards the military application of explosives, there is nothing in the results of these trials to disturb the firm conviction of our Government that gun-cotton is the best adapted for torpedo charges, submarine mining, and hasty demolitions of all kinds. Its superiority in local force to dynamite, when employed without any confinement, is once more strikingly demonstrated, to say nothing of the far greater safety of wet cotton and its applicability for use under water with no other confinement than that of a net to keep the slabs together. But although quite outside the scope of Tuesday's experiments, the great power and perfect safety of roburite seem eminently to fit it for use as a bursting charge for shells, into which its granular form would allow it to be conveniently loaded. Much stronger than any picric powder, and doubtless better able to withstand the concussion of the discharge of the gun, an extended series of trials would be necessary to determine the best mode of so employing it. (*Engineering*, 43, 573, 574, June 17, 1887.)

The *Army and Navy Journal*, October 1, 1887, quoting from the *London Times*, gives the name of the reported new Russian explosive *

* Proc. Nav. Inst. 13, 248; 1887.

as Sleetover, and states that it is equal in strength to pyroxyline, and very cheap. "Another great superiority which it possesses over all the known explosives of the dynamite class is that when fired its force does not strike downward, but entirely in a forward direction, so that it can be used for all the purposes of cannon and musket charges to which ordinary gunpowder is now applied, without any damage whatever to the weapon from which it is discharged. It is stated, in fact, that ball cartridges loaded with it have been fired out of card-board barrels, as a test, without the least injury to the latter."

The "new Swedish explosive," bellite,* discovered by Mr. Carl Lamm, director of the Rönneby Explosive Manufactory, Limited, near Stockholm, consists of ammonium nitrate and dinitro benzene, which, when in a melted condition (the melting point is 80° to 90° C.), are mixed with saltpetre, forming a compound of which each molecule explodes. Bellite, when pressed warm, has a specific gravity of 1.2 to 1.4 in its granulated state, which, according to the experiments already made, seems to be the one best suited for military purposes. One litre of bellite weighs 800 to 875 grams.

Heated in an open vessel bellite loses its consistency at 90° C., but does not begin to separate before a temperature of 200° C. is reached ; at that point evaporation begins, and increases with a higher temperature, without, however, explosion occurring. If the heating is sudden, bellite will burn with a sooty flame, something like tar ; but if the source of the heat is removed, the bellite will cease burning and assume a caramel-like structure, the ingredients being the same as in its original state, with the exception of a somewhat reduced proportion of saltpetre. The explosive appears to absorb little moisture from the air after it has been pressed ; if this operation is performed in the hot state, the subsequent increase of weight is only 2 per cent.

From the experiments of Werner Cronquist and Professor Cleve we learn that when bellite is subjected to the most powerful blow a man is capable of inflicting with a steel hammer upon an iron plate, it becomes heated, but neither explodes nor ignites. Two grains of bellite in a blank copper cartridge (that of a Remington rifle) were placed on an iron plate and subjected to the fall of a weight of 200 pounds from a height of 17 feet 6 inches, without exploding. Layers of bellite .47 inch in thickness on wood or iron have been pierced with rifle balls fired at a distance of some 50 yards, without showing

* Proc. Nav. Inst. 13, 247-248 ; 1887.

signs of exploding or ignition. While boring in cast iron with a steel drill, one grain of bellite has been placed in the hole, neither explosion nor ignition having resulted, although no sort of oil or other lubricator was used. A small quantity was fixed to the pointed end of a steel rod, and the rod knocked so hard against quartz as to produce sparks, yet there was no explosion. A good sized piece of bellite was placed in an open tin box and covered with gunpowder, the latter was ignited, the explosion throwing the bellite several yards in the air, but it did not explode. In a piece of hard wood a hole was made of the size of a penholder, two grains of bellite were pressed hard into the hole and this closed with a wooden cork. The wood was thrown into a coke fire and consumed, but there was no explosion. A compressed bellite cartridge was placed close to a rocky wall, and some three inches from it a cartridge of nitrolite (nitroglycerine, gun-cotton and nitrate of ammonia); the latter charge was made to explode by a Stubine percussion cap, and after the explosion the bellite cartridge was found to have been crushed, and the powder into which it was turned was fixed to the rock. The bellite had consequently not exploded. The list of these experiments might be considerably increased, but sufficient has been said to prove that bellite can withstand blows, fire, friction, and vibration, without the slightest risk of explosion. It can be safely transported by rail, and stored without any danger of spontaneous combustion.

Granulated bellite is caused to fully explode by the aid of a small quantity of fulminating mercury, even if its cover only consists of thin tin. When pressed warm, especially when it is in the form of hard cakes, it requires a stronger impulse and a stronger cover, which must adhere to the bellite.

The suitability of bellite as an explosive for grenades (when these are provided with a proper percussion tube) has been established through a series of experiments carried out by officers of the Swedish Royal Artillery. A series of experiments has been made by exploding under water, mines loaded with bellite against a dynamometer. The average of several explosions gives, at a distance of 17 ft. 6 in., a blow of equal power to that caused by a weight of 22 pounds falling from a height of 39 in. At a reduced distance of 12 ft. 6 in. the effect was proportionately increased. On comparing the efficiency of bellite with that of gun-cotton, under exactly similar circumstances, the former shows a superiority of 10.4 per cent at a distance of 17 ft. 6 in., and of 15.2 per cent at a distance of 12 ft. 6 in. The firing of 25-

millimetre machine-gun ammunition and steel bullets against mines loaded with bellite had not the least effect upon the explosive, thus proving it to possess a great advantage in this respect over other explosives generally used for submarine mines.

It is the opinion of those who have had the best opportunities of judging, and whose verdict is of acknowledged authority, that bellite bids fair to become of great importance; that it is equally suitable for mining and military purposes, while it is not so liable to be put to an undesirable use as are most other powerful explosives. (*Engineering*, 44, 18, July 1, 1887.)

The press reports that an accidental explosion of melinite occurred at the arsenal at Belfort, March 10, 1887, by which six men were killed and eleven wounded. The *Army and Navy Journal*, May 14, states that in spite of this accident, and of a more recent one at Bourges, the belief in the new explosive is not abandoned, and that shells filled with it are to be tried against the Belligueuse, one of the early iron-clads, of 3617 tons displacement. The Germans, however, claim to have proved by experiment that melinite decomposes if kept long, and is therefore useless for war purposes.

U. S. Letters Patent No. 350048, September 28, 1886, have been granted to Eugene Dupont for a gunpowder press, in which two hydraulic rams, furnished with pins, work through each face of the mold plate. The result of this operation is that the powder in the apertures of the mold plate is compressed with equal force at both ends, and large grains of the desired dimensions and form (cylindrical or prismatic) are produced, in which the ends of the grains, being compressed with equally-moving pistons or rams, are both hard, while the central parts of the grains are comparatively soft when the grains are removed from the molding apertures. A grain of such construction, having two hard ends and a comparatively soft centre, is of great advantage in firing large ordnance, as it burns with great rapidity from the centre as well as the ends when once started, though the initial rate of combustion is slow, owing to the compacted ends. What he claims is—

In a machine for forming grains of explosive compounds, the combination of a fixed mold plate containing suitably formed apertures for molding powder; two equally-moving and balanced rams acting to compress the grains from both ends, and pins passing through the

apertures in said mold plate and having a longitudinal motion therein independently of said rams, substantially as and for the purposes described.

U. S. Letters Patent No. 352611, November 16, 1886, have been granted Eugene Dupont for an explosive compound, in accordance with the following specification :

My invention consists in the use, in explosive compounds, of wood slightly changed in its chemical formula by the application of heat for the two purposes of increasing the ballistic force of the powder and of controlling the rate of combustion so as to adapt it for use in heavy charges behind projectiles of great weight, or to lighter charges in medium sized guns. With this end in view, I replace (either wholly or partially, as desired), the charcoal which is used in the composition of ordinary gunpowder, with the requisite amount of wood slightly changed in its chemical formula by having been subjected to heat or baked, as hereinafter described.

I have found that branch-willow wood is well adapted to the purpose ; but any suitable wood for making gunpowder charcoal may be used.

I subject the wood to a gentle heat (either in a retort over a slow fire, or by the application of superheated steam in a suitable vessel), gradually raising the temperature to about 450° Fahrenheit, at which the heat is maintained for about two hours (this would be for three-fourths of a cord of willow), the entire time consumed in the baking being about eight hours, six hours being consumed in obtaining the proper temperature. The limits of temperature at which the baking should cease (as far as I am now aware) to secure good results are 300° Fahrenheit and 450° Fahrenheit, the lower temperature making the wood less rapidly combustible, and the higher securing a more combustible wood. The process of heating the wood, as described, should cease before the wood is transformed into red charcoal, which is useless for my purpose, as red charcoal has entirely lost the fibrous character of the wood, while in the wood which I use in the present invention the fibre is still undestroyed ; and it is by breaking the wood and examining if the fibre has been destroyed that I am able to determine the point at which the baking should cease. 450° Fahrenheit is a temperature high enough to transform the wood into red charcoal, if maintained for a length of time ; but I remove the wood before such transformation takes place.

My baked wood differs from red charcoal not only in its physical character by retaining its fibre, but also in its chemical formula. Red charcoal is considered to contain about 72.64 per cent of carbon, 4.71 per cent of hydrogen, 20.08 per cent of oxygen, and 0.57 per cent of ash. Although not a definite chemical compound, but being produced by partial decomposition, it will vary slightly in its formula. This also applies to my baked wood, which may vary even more than from 47.51 per cent of carbon, 6.12 per cent of hydrogen, 4.29 per cent of oxygen, and 0.08 per cent of ash, to 51.82 per cent of carbon, 3.99 per cent of hydrogen, 43.94 per cent of oxygen, and 0.22 per cent of ash; but, as will be seen, it has much less carbon than red charcoal, and still less than black charcoal. The carbon in my baked wood also retains to a certain extent, after being ground fine, its cellular form, and combines with the liberated oxygen from the salt-petre more readily than other forms of carbon, for instance, stone coal or lamp black.

The greater proportion of the oxygen and hydrogen in my baked wood than in charcoal is of very great importance to the ballistic effect of the powder. The theory of their action, as proved by experiment, is as follows: The temperature, after ignition of the charge in the gun, reaches 4000° Fahrenheit, a degree of heat too high to permit the oxygen and hydrogen to combine to form water, and they therefore must remain uncombined until, by the expansion due to the motion of the projectile toward the muzzle, these gases are cooled sufficiently to permit their union. When this takes place, a very large amount of heat is disengaged, which expands again the steam and other gases formed by the combustion of the powder. The pressure thus sustained while the projectile is in the gun insures a high velocity and a low pressure, because all the atoms of the powder cannot form new combinations at the time of ignition, but part of them unite as the pressure falls. It is therefore important to get as much of the substances containing oxygen and hydrogen in proportions to form water, or approximate proportions, into the powder as possible, and I therefore prefer the baked wood, which contains these gases in such proportions, besides having its carbon, as stated, in a form to unite readily with oxygen. The fibrous character of my baked wood also gives toughness to the grains of powder and prevents the grain from breaking up too rapidly.

It is unnecessary to describe the method of combining the components of powder, for that is well known, but I have found the following

ingredients and proportions to form a desirable powder for guns of twelve-inch calibre: saltpetre, seventy-eight parts, by weight; sulphur, three parts; baked wood, 12.5 parts; ordinary wood pulp, 2.5 parts; sugar (the use of which forms the subject of my application for letters patent, filed August 12, 1885, No. 174214), four parts; or, as I have also found the wood pulp may be omitted, as the grain will be toughened by the fibre of the baked wood, the proportions in this case being about as follows: saltpetre, 78.95 parts, by weight; sulphur, three parts; baked wood, 15.02 parts; sugar, 3.03 parts.

I do not limit myself to the special ingredients or proportions given above, as my invention consists in the combination of baked wood, as herein described, with well known gunpowder ingredients, and other equivalent ingredients may be substituted for those above mentioned.

What I claim is—

An explosive compound consisting of a nitrate and sulphur combined with charcoal retaining its fibrous structure, substantially as described.

In U. S. Letters Patent No. 363887, dated May 31, 1887, Eugene Dupont claims to have invented a new and useful compound, principally for use in guns of medium and large calibre, of which the following is a specification:

The first object of my invention is to obtain an explosive which shall have great ballistic force; and its second object is to obtain a powder which shall obviate, as far as possible, the many disadvantages pertaining in a greater or less degree to all artillery explosives, and which consists in the smoke arising from the burning powder, such smoke obscuring the view and interfering with the sighting for a second shot.

I have found by experiment that substances having in their component parts the elements of hydrogen and oxygen in such proportions that, upon being released from the rest of the component parts by combustion, they will combine to form water and steam, and greatly increase the explosive force of the powder of which they form a constituent element. The action of such powders seems to be as follows: Upon firing the charge, the gases confined in the powder are released, and act to expel by their expansion the projectile toward the muzzle of the gun. This I term the "first explosion." At this time the oxygen and hydrogen are released as gases, but under too

great heat to unite in the form of steam. As the pressure is decreased by the motion of the projectile in the gun, this heat also decreases, and the gases—oxygen and hydrogen—unite in the form of water. The heat generated by this union at once changes the water into steam, and this expansion, which takes place before the projectile leaves the muzzle of the gun, I term the “second explosion.” There is thus formed a powder of great explosive force, which acts twice upon the projectile. I have also found that such powders are very effective in dissipating the smoke arising from the discharge, owing, as I suppose, to the fact that the steam, generated as above stated, condenses, and in so doing absorbs large quantities of the carbonate of potash, the solid portion of the result of decomposition of a charge of powder and that portion which forms the smoke.

Thus I employ in place of the carbon usually used in the composition of explosive powders, the substances known as “carbohydrates,” and which have the chemical formula of cellulose, $C_6H_{10}O_5$, or an approach to it, such as wood pulp, starch, dextrine, etc., or other substances, such as sugar, having substantially the chemical formula of $C_{12}H_{22}O_{11}$. All such substances having substantially the formulas aforesaid, and the capacity of forming water and steam by the action of the explosion, I term in this specification “carbohydrates.” Instead of using one substance having the required chemical formula, two or more may be used having the necessary elements separate, which, when liberated, will combine to form steam and act in the manner required.

The materials should be mixed in a finely divided condition, and it is better to mix the carbohydrates with the other ingredients of the powder after such other ingredients have been mixed, as such carbohydrates are apt to be gummy in their nature.

I have found, for example, that a very effective powder may be made of the following substances, in substantially the proportions specified, viz., saltpetre (for which other known nitrates may be substituted) 78 parts, sulphur 2.8 to 3 parts, carbohydrates 3 to 4 parts, charcoal retaining its fibrous structure 12 or 12.5 parts. This powder, to be most effective, should be made in prismatic grains, and I have found that the best results are obtained by so constructing said grains that they are less dense in the middle than at the ends, which therefore have the particles more compacted together at those points than in the middle. My method of making these grains of such varying density is described in an application for letters patent,

filed August 12, 1885, Serial No. 167749. Such form and construction of the grains retard the development of the gases from combustion, until it is desired to obtain the maximum force; and I find that the fibres of the charcoal, retaining its fibrous structure referred to, materially aid in this result, as they tend to prevent the grains of powder from becoming broken up. The use of charcoal retaining its fibrous structure, as above referred to, forms the subject of an application for letters patent, filed June 5, 1885, Serial No. 167748.

What I claim is: 1. An explosive compound consisting of a nitrate, sulphur, charcoal retaining its fibrous structure, and a carbohydrate, substantially as described.

2. An explosive compound consisting of saltpetre, sulphur, charcoal retaining its fibrous structure, and sugar, substantially in the proportions specified.

From *Ding. Poly. Journal*, 263, 149; 1887, we learn that the composition of the brown prismatic powder sometimes known as cocoa powder is yet a secret, but it has been suggested that the charcoal used in its manufacture is made from peat, and the mysterious actions of the inventor tend to confirm this opinion. It is stated also that charcoal for this purpose is made at Chilworth and elsewhere by the action of superheated steam on rye straw.

We have frequently been asked to state to what the properties which distinguish the brown prismatic powder are due, and we trust it may not be considered out of place if we state our theory in this connection.

We hold that its property of imparting a high initial velocity to the projectile, while only exerting a relatively low pressure on the walls of the gun, is due to the combined action of a number of causes, viz:

1. The form of the grain; 2. the size of the grain; 3. the great density of the grain; 4. the great hardness of the grain; 5. the small percentage of sulphur; 6. the easy inflammability of the charcoal or carbohydrates; 7. the relatively great heat evolved; 8. the simplicity of the chemical reaction.

Cause 5 tends to reduce the readiness with which the powder will ignite, or raises its point of ignition, even when the grain is pulverized. Causes 1, 2, 3, 4, and 5 combined operate, so long as the first four exist, to produce a very slow rate of combustion. By the time, however, that the projectile is moved from its seat, the grains will be

reduced in size and more or less broken up. We shall then have a fine-grained powder which is highly inflammable at the temperature which exists (cause 6), and consequently the volume of gas evolved will increase rapidly as the volume of the chamber increases. Owing to the relatively great quantity of heat evolved (cause 7), the cooling effect of the envelope is less marked than with other powders. As the chemical reaction is a comparatively simple one (cause 8), the speed of the reaction is probably more uniform than when the reaction is more complex, as in other powders.

According to Berthelot, dissociation plays an important part. This is possible, and even probable, with powders made from underburnt charcoal, as this contains carbohydrates, or with those in which the carbohydrates are a constituent of the mixture.

The advantage of the form of grain employed was pointed out by Rodman,* the inventor, and his views have been confirmed by Sarrau.† The advantages of size, density (this is 1.86 in cocoa), and hardness are commonly known. Berthelot and Vieille‡ have shown that the hydrates of carbon, such as cellulose, contain an excess of energy above that given by the carbon and water which their decomposition would furnish. And Noble states,§ in his lecture on the “Heat-Action of Explosives,” that a unit mass of cocoa powder yielded a greater number of units of heat than any other of the standard powders, which Abel and Noble tested, yielded. He also shows|| that the chemical reaction attending the combustion of cocoa powder is simpler than that attending any other.

U. S. Letters Patent No. 362899, May 10, 1887, have been granted to Thorsten Nordenfelt, of Westminster, England, and Victor A. Meurling, of Christianstad, Sweden, in accordance with the following specification :

At the present time, in the manufacture of gunpowder, it is usual to incorporate the sulphur and saltpetre with the other materials by a process of grinding. This grinding is a dangerous operation after the saltpetre is added, and it has to be long continued in order that the mixture of the materials may be sufficiently intimate. Now, in place

* Experiments on Metals for Cannon and Cannon Powder, 291-297 ; Boston, 1861.

† Proc. Nav. Inst. 10, 160 ; 1884.

‡ Proc. Nav. Inst. 12, 187 ; 1886.

§ Heat in its Mechanical Applications, Inst. Civ. Eng. Lond., 211 ; 1885.

|| Loc. cit. 209.

of thus producing a mechanical intermixture, which, after all, can only result in placing minute particles of sulphur, saltpetre and charcoal side by side, we bring the sulphur to a state of solution in bisulphide of carbon, and in this state we combine it with suitable carbonaceous matter. In this manner we diminish risk in manufacture, we manufacture the powder more cheaply, and obtain a powder which is more even in its results.

If it be deemed desirable to use wood charcoal, it may be employed as the carbonaceous matter in the manufacture of the gunpowder in carrying out our invention; but as we have found cotton or wood fibre or other like vegetable fibre reduced to a state of fine powder by a chemical process a preferable carbonaceous matter, we employ it. The vegetable fibre, whether it be cotton or wood fibre such as is used in paper making, or other vegetable fibre, is placed in a loose state in a vessel through which a current of hydrochloric gas is caused to pass so that it may permeate the fibre. After a time the fibre will be found in a friable state, such that it may easily be reduced to powder by friction. The current of hydrochloric gas is then stopped, and is replaced by a current of air, which is continued until the gas is thoroughly expelled.

The following is the manner in which we conduct the manufacture of gunpowder: The ingredients are sulphur, saltpetre, and the carbonaceous matter. The materials should be pure, and the proportions the same as now used in gunpowder, subject to variation to some extent, and, as is now usual, to adapt the powder to the various purposes for which it is required.

We first grind the carbonaceous matter to a very fine powder, the finer the better. We prepare the sulphur for use by dissolving it in bisulphide of carbon. The solution is effected by the aid of a gentle heat in a water-bath, and the evaporation of the bisulphide may be prevented by covering its surface with a layer of water. A saturated or nearly saturated solution should be thus prepared. The pulverized carbonaceous matter and the solution of sulphur in bisulphide of carbon are then thoroughly mixed together in a closed vessel containing a mechanical stirrer. When the mixture is complete, the solvent is evaporated or distilled off by the aid of a gentle heat. The vapor of the bisulphide is collected and condensed, so that the solvent may not be lost. The means for this purpose may be such as are employed when this liquid is used in the preparation of extracts and for like purposes. When the bisulphide of carbon is evaporated, the

carbonaceous matter and sulphur remain intimately mixed, and each particle of carbonaceous matter has become impregnated with sulphur, instead of as at present, where the admixture is obtained by grinding, the particles of carbonaceous matter and sulphur being only mechanically placed side by side. The saltpetre is prepared for use by dissolving it in water, the solution is added to the pulverized carbonaceous matter already impregnated with sulphur as described above, and the whole is stirred together in a mechanical mixer.

We find it advisable not to add the whole of the saltpetre at one time, but to divide it into two or three separate quantities, and with each quantity we have sufficient water to render it sufficiently fluid for impregnating the carbonaceous matter already impregnated with sulphur.

After each admixture the water is separated by evaporation, and heat may be applied to hasten this evaporation, but in such manner as to avoid risk of the materials igniting as they become dry. After the first drying operation the material, in a state of powder, is again mixed with saltpetre solution, and it is afterwards again dried as before, and so for three or more times, should it be considered desirable to divide the operation of incorporating the saltpetre into so many operations. When the incorporation of the saltpetre is complete, it only remains to finish the powder for use by ordinary methods. It may be compressed into cakes or prisms, dried, broken up, and granulated in the usual manner.

By this method the dangerous process of grinding the powder after it has been rendered explosive by the addition of the saltpetre may be altogether avoided; or if in any case it should be considered advisable to resort to a grinding process after the materials have been mixed in the manner above described, the danger would be much less than at present, because of the lessened time during which the grinding would be continued.

The carbonaceous matter may also be submitted without risk to a grinding operation after the sulphur has been incorporated with it and before the saltpetre is added.

Although our invention is mainly intended for the manufacture of gunpowder from the ordinary ingredients, it is also applicable to the manufacture of like compounds in which the saltpetre is replaced by nitrate of soda or other salt capable of furnishing the oxygen to the carbonaceous matter and sulphur.

In the preparation of the cotton or vegetable fibre, liquid hydrochloric

acid may be employed ; but the use of the gas, as herein described, is preferable.

Having thus particularly described and ascertained the nature of our said invention and the manner of performing the same, we declare that what we claim is—

1. As an improvement in the manufacture of gunpowder, the method described of incorporating the sulphur with carbonaceous matter, which consists in dissolving the sulphur in bisulphide of carbon, impregnating the carbonaceous matter with the solution so obtained, and separating the bisulphide of carbon by evaporation, substantially as set forth.

2. As an improvement in the manufacture of gunpowder, the method described of incorporating the sulphur and saltpetre or equivalent salt in the carbonaceous matter, which consists in dissolving the sulphur in bisulphide of carbon, impregnating the carbonaceous matter with the solution so obtained, separating the solvent by evaporating ; also impregnating the carbonaceous matter with saltpetre or equivalent salt in solution, and separating the solvent by evaporation, substantially as set forth.

3. The hereinbefore described method of manufacturing gunpowder, which consists in treating cotton or equivalent vegetable fibre with hydrochloric acid (either gaseous or liquid) to obtain carbonaceous matter* with the sulphur and saltpetre, substantially as set forth.

From *Rept. H. M. Insp. Exp.*, p. 44 ; 1885, we learn that an explosion took place in a factory in which gunpowder was being made by Mr. Nordenfeldt's process. The accident was wholly due to carelessness, but the inspectors found that the presence of bisulphide of carbon in powder tends to sensibly lower the point of ignition.

U. S. Letters Patent No. 359289, March 15, 1887, have been granted to Edward Schultze, of Darmstadt, Germany, in accordance with the following specification:

The improvements in the manufacture of gunpowder and similar explosives consist in the composition and combination of three kinds of materials—of a nitro-hydrocarburet with pyroxyline, and thirdly, with a nitrate or salt, formed by the union of nitric acid with a base, and furnishing a compound of oxygen and nitrogen. By mixing these three constituents in various proportions I am able to produce

* *Proc. Nav. Inst.* 8, 309 ; 1882.

an explosive of greater or less force. When this mixture is to be used as gunpowder for shooting purposes, I take a certain amount of the pyroxyline and diminish the rending force of the pyroxyline by adding nitro-hydrocarburets and nitrates; but when I wish to use said mixture as a blasting explosive, for blasting hard rocks or minerals and other blasting purposes, I augment this amount of pyroxyline with a view to producing greater rending force. When burning, these mixtures are free, or nearly, from noxious fumes, residue, and recoil. I instance, as belonging to the hydrocarburets which I employ in my mixtures, common resin or colophony, tar, turpentine, or turpentine oil, after having treated them with nitric acid. I instance, as belonging to the pyroxylines which I employ, nitro-cellulose (cotton or wood, or any vegetable fibre). I include the different varieties of pyroxyline, and instance the form commonly called gun-cotton. I instance as nitrates those of baryta, potassium or sodium, lime and ammonium. By different combinations of these constituents I am able to produce every class of explosives suitable for all purposes. I can use them, for instance, in the place of dynamite, for blasting hard rocks or minerals, treating the convenient mixture under hydraulic pressure; or in the place of black gunpowder, for blasting rocks or minerals less hard, or in the bombs and shells of the artillery. I can also employ my explosive as a filling for cartridges to be used in coal mines subject to fire-damp. These cartridges will not ignite the fire-damp, and thus obviate a fruitful cause of accidents. I can also choose another percentage in mixing the three constituents, so that the explosive is then suitable as gunpowder for sporting and military purposes.

I will now give examples of the proportions to be used in preparing explosives according to my invention, but I wish to be understood that they are given as the best proportions with which I am acquainted for carrying my invention into effect, and that I do not limit myself to the precise details given in these examples, as I can advantageously vary the proportions in the same manner as the black gunpowder-makers can and do vary their proportions of charcoal, sulphur, and saltpetre to produce explosives suited to various requirements.

The proportions hereinafter given are by weight. A powder suitable for sporting purposes can be made according to my invention by mixing twelve parts of nitro-tar, or colophony, or turpentine, or turpentine oil, or mixtures of them, with sixty to eighty parts of pyroxyline, sixty to eighty parts of nitrate of baryta, and eight to ten parts of nitrate of potassium.

This mixture is prepared and granulated in the well known manner prevalent in making black gunpowder. I may add some binding material or not, and the grains of the finished powder may be coated or not with substances fit for this purpose, such as paraffine, resin, or collodion.

Not more than five-eighths of this gunpowder for sporting purposes thus produced should be used in the place of the quantity of black gunpowder that is generally used for this purpose. The propelling force of the sporting powder thus produced is excellent, and the rending force is not greater than that of black gunpowder, and it is free or nearly free from objectionable fumes, residue, and recoil.

A good gunpowder for rifles is produced by mixing ten parts of nitro-tar, colophony, turpentine, or turpentine oil, or mixtures of them, with two hundred and eighty to three hundred parts of pyroxyline, one hundred to one hundred and twenty parts of nitrate of baryta, forty to fifty parts of nitrate of potassium, and about ten parts of sulphur.

This mixture is to be granulated in the same manner as the sporting gunpowder, and should be employed in quantities of about two-fifths the weight of the quantity of black gunpowder used for analogous purposes—such, for instance, as that for military rifles. The finished powder may be coated or not, as mentioned with respect to the sporting powder.

My blasting explosive, suitable for use in blasting mild rocks or minerals, has a little proportion of pyroxyline. I may also add to this explosive a quantity of sulphur.

The proportion of the materials may with advantage be about ten parts each of pyroxyline and sulphur, fifteen parts of nitro-hydrocarburets, and seventy-five parts of saltpetre. The greater the proportion of pyroxyline the greater will be the power of the explosive produced, so that when an explosive is required for blasting hard rocks or minerals, the proportion of pyroxyline should and can be increased to suit the purpose for which it is required.

Having fully described my invention, what I desire to claim, and secure by letters patent, is—

The composition, consisting of a nitro-hydrocarburet (such as nitro-colophony, tar, turpentine, or turpentine oil), and of pyroxyline, and of nitrates or salts furnishing oxygen in combination with nitrogen, for shooting and blasting purposes, substantially as described.

According to the *Army and Navy Gazette*, 28, 673; August 13, 1887, a series of trials has taken place at the Middlewick Ranges, Colchester, to test the relative merits of the Government cartridges, as loaded for the Enfield-Martini rifle, and others filled with a newly invented smokeless powder, which has been patented by Messrs. Johnson and Borland. The trial was carried out with a Gardner gun. The first trials consisted in firing 40 rounds of Government ammunition, so as to foul the barrel, and then 10 shots from the dirty barrel to test the accuracy. Although the gun had been well "laid" before the firing of the 10 shots, only 4 at 800 yards hit the target. The barrel was found to be very foul. The same number of shots were then fired with the "Johnson-Borland powder," with the result that in the last 10 of 50 rounds 8 struck the centre of the target. Then the barrels were inspected and compared and found comparatively clean. Indeed, once passing through the cleaning rod removed all residue, whereas it took 7 damped tows to clean the barrel in which the black had been fired. Trials for speed were then made, 40 rounds being fired in $5\frac{1}{2}$ seconds. It was found that in consequence of the strain of the new powder being so small, the handle of the gun could be revolved with so much ease that the gun in rapid firing was not put out of position. The explosive force of the Government ammunition was such as to necessitate much more power being exerted in revolving the crank handle—a serious defect—whilst at the same time the "kick" was much greater. Besides this, the smoke from the Government ammunition was such that, after firing 20 rounds rapidly, the smoke accumulated so as to prevent No. 1 seeing through it; whereas with the new powder it was quite possible to see the bull's-eye at any time during the rapid firing. The velocity of the Government ammunition in the Enfield-Martini rifle is 1570 feet per second, which is the highest of any arm in the European service. With the new powder, 1800 feet per second has been arrived at. The experiments at Colchester show that the days are approaching when a smokeless explosive is likely to take the place of the present powder.

German Letters Patent No. 37631, October 14, 1885, have been granted to Friedr. Gaens, of Hamburg, for a gunpowder without sulphur, but which contains an ammonium salt, which will give rise to the formation of a potassium amine which is to be converted temporarily, at a higher temperature, into the explosive potassium nitride. (*Dingl. Poly. Jour.* 263, 152; 1887.)

The *Scientific American*, p. 177, March 19, 1887, under the title Improved Gunpowder, states that A. H. Durnford has patented a process for making a soft charcoal which shall have an extremely low density, a low point of ignition, and slight hygroscopic properties, and which will produce a gunpowder possessing great energy and propelling power combined with moderate pressures when fired in a gun. The novelty consists in using charcoal made from cork by subjecting the cork to destructive distillation in cylinders at such a temperature as will produce the desired result. The gunpowder consists, first, of saltpetre and cork charcoal in the proportions of 80 to 20 respectively; second, of saltpetre, cork charcoal and sulphur, the latter being in proportions varying from 1 to 10 per cent. It is claimed that this powder is comparatively smokeless and non-hygroscopic.

It is now a well known fact that when compressed gun-cotton, dynamite, or other high explosives are freely exposed upon a metal plate and detonated, if the plate is sufficiently strong to resist rupture, the explosive leaves a marked and permanent impression upon the plate; the intensity of the impression being, of course, dependent upon the intensity and amount of the explosive used. This is not surprising when we recall that Berthelot found that gun-cotton having a density of 1.1 will develop, when in contact, a local pressure of 24,000 atmospheres or 160 tons on the square inch, and if we remember, too, that this enormous pressure is realized in an exceedingly brief space of time. The effect may of course be enhanced if the explosive be tamped with earth, water, etc. But, as Cooke* has so clearly shown in his essay on the "Air as an Anvil," the aerial fluid may serve as a tamp just as the aqueous one does, though not as efficiently.

It is perhaps not so well known a fact that the impression produced by the exploding mass is an almost exact copy of the form of that surface of the explosive which was in contact with the plate of metal. This feature is best observed with compressed gun-cotton, since, as it is a *papier-maché*-like body, it is possible to shape it as we fancy and to stamp upon its surface such figures and designs as we wish.

The first recorded observation of this phenomenon of which we are aware, is that made by Lieutenant Max Von Förster, of Walsrode, and a translation of his paper may be found in *Van Nostrand's Eng. Mag.*

* Pop. Sci. Monthly.

31, 113, August 1884. He says that when a piece of compressed gun-cotton is detonated on a plate of iron, an accurate impression of the form of the under surface of the gun-cotton is produced. Every angle, every projection, and every indentation present in the gun-cotton is impressed on the underlying iron, and he claims that this is due to the fact that the gases acting on the iron have occupied exactly the same space and no more than the solid explosive previously occupied, and thus transferred its form, and hence he concludes that only the gases evolved by the very undermost layers of gun-cotton act on the iron, while the others are lost.

In *Van Nostrand's Eng. Mag.* 32, 1, January 1885, we have given an illustration of similar impressions which we had observed previous to meeting with Von Förster's paper, and we advanced the opinion there, and subsequently in our Notes,* that it was due to projection, the residual gun-cotton being driven into the metal by the explosion of a portion of the original mass, just as any other resisting body interposed in the path of the explosive wave would have been. Of course we are met here by the difficulty that this hypothesis implies (1) that the pressure exerted upon the residual mass of gun-cotton is transmitted more rapidly than the explosive reaction is propagated within the mass, and (2) it implies also a great rigidity or coherency for this mass. The last condition requires that which is a property of masses of matter when moving at high velocities, as in the well known candle experiment, and in the cutting of steel by soft iron, and the like. The difficulties presented in the first condition do not seem so great as those in Lieutenant Von Förster's hypothesis.

Some months subsequent to this, Commander T. F. Jewell, U. S. N., read a paper before the American Association for the Advancement of Science, on "the apparent resistance of a body of air to a change of form under sudden compression," and presented as an example of this phenomenon an iron plate upon which a disk of gun-cotton had been detonated. The letters U. S. N. and the figures 1884 had been indented in the surface of the gun-cotton, and similar letters and figures were found indented in the plate. He held that this was due to the fact that the air enclosed in the letters and figures, under the sudden and enormous pressure to which it was subjected, acted like a hard body and was thus driven into the iron. This paper appears in the *Proc. American Association* 34, 81; 1886.

In a later pamphlet (Berlin, 1886) Von Förster again states that the

* *Proc. Nav. Inst.* 11, 110, Feb. 1885.

gases generated by the detonation of the gun-cotton have, in the first instant, and as long as they exert their maximum force, the exact form and occupy the same space as was occupied by the gun-cotton before detonation, and thus they produce an exact impression of the surface of the gun-cotton in contact with it. He also says that the suddenness with which the power is exerted is shown by placing a leaf between the gun-cotton disk and the iron, for, after detonation, the whole frame or skeleton of the leaf will be found raised upon the iron. He explains that this is due to the larger as well as the smaller ribs of the leaf protecting the underlying parts of the iron, while the thinner parts between could not yield such protection, and under them the impression is deeper.

This was the condition of the subject when we again took it up experimentally in 1886. We first detonated gun-cotton disks upon which the figures and letters were indented, and obtained impressions on the plates in which these were also indented. Next we used disks having raised letters and figures, and obtained impressions in which these were raised. Next we cut deep channels in the disks, of various forms, taking care that they always communicated with the outer air so that there would be no air confined in them, and again these indentations were exactly reproduced in the iron. Next we filled the indented letters and figures, in disks such as Jewell used, with paraffine and with vaseline, so that the material was flush with the surface of the disk, and on detonation the letters and figures were found to have been obliterated. Next we struck, with stamps, the same letters and figures in an iron plate. This plate was laid face downwards on another iron plate and a lettered gun-cotton disk placed on top and detonated. The result was that while the gun-cotton disk produced the usual indented letters on the back of the top plate of iron, the top plate in whose letters and figures air was also confined and which was subjected to the same blow, produced raised letters and figures on the bottom plate on which it rested. These last three experiments certainly seem to prove that the air has nothing to do with this action. Again, when we consider how enormous the pressure is to which this air is subjected we must believe that, no matter how suddenly the force is applied, the air must undergo some compression, yet we find that the indentations in the iron are often nearly as deep as those in the gun-cotton.

In considering Von Förster's hypothesis, we are willing to admit that the gases at the time of detonation possess the exact form and

occupy the same space as the gun-cotton from which they are formed, if the change takes place instantaneously. But it does not; in fact, it occupies so appreciable a period of time that the rate of propagation of the detonation in it has been measured. Apart from this, and even granting it, it will be observed that Von Förster does not explain how the impression is to be produced by the gas. If the gas moves as a solid body, then the impressions should be the reverse of what we get.

From our experiments we are the more strongly convinced that the effect is a purely ballistic one, and that while the base of the gun-cotton, or its products, are projected as a whole against the plate, where the intervening spaces are the greatest there we have the greatest effect of impact, and consequently the greatest indentation. This is true in the leaf experiment, which has been exquisitely reproduced. The varying thicknesses of the leaf vary the distances through which the material is projected, and hence the form and texture are reproduced in the impression.

These experiments were described before the *Am. Assn. Adv. Sci.* in August, 1887, and the plates exhibited there have been very accurately and beautifully represented in the *Sci. Am.* 57, 223, October 8, 1887; but the editorial description is inaccurate in some particulars. In the same paper are illustrations of the application of gun-cotton for testing the resistance of metals to shocks, as described in these Proceedings.* It should be stated that this method gives a means for revealing the inner structure of metals in masses such as we have never before possessed.

A new way of utilizing dynamite has been lately devised by a French military engineer, M. Bonnetond. He uses the expansive force to drive out, for a brief period, the water from portions of wet ground in which foundations are to be made. The method is now in practice in the construction of a fortified *enceinte* at Lyons. A hole is first bored 10 or 12 feet and about 1½ inches wide in the wet ground. Into this is passed a string of cartridges of dynamite, which is then exploded. The water is thus driven far out beyond the sides of the cavity, over a yard wide, which is produced, and does not reappear till after half an hour at least. The workmen thus have time to clear the cavity and introduce quickly-setting concrete. When the water returns it cannot injure the foundation. A rapid rate of progress is realized by this method. (*Nature*, 36, 564; 1887.)

* Proc. Nav. Inst. 13, 116; 1887.

The *Boston Globe*, July 22, 1887, notes that the balloon department of the German army is experimenting with a view to trying the destructive effect of dynamite hurled down upon forts from a balloon. In the *Sci. Am.* p. 181, March 19, 1887, W. Maxwell Maynard proposes that large fire balloons, to which a charge of dynamite is attached, be sent up among the rain clouds and discharged there in order to precipitate a rainfall in dry weather.

A new method of blasting without explosives has been recently introduced by Dr. Kosman, and is described in *Jour. Inst. Civ. Eng.* 87, 41. Zinc powder and sulphuric acid are contained in a glass cartridge, by breaking which the two substances are brought in contact and hydrogen is rapidly evolved. A pressure of about 37,000 atmospheres is obtained, although, perhaps, with hardly sufficient rapidity to justify the use of the term explosion. (*Engineering*, 43, 67, Jan. 21, 1887.)

A. Cavazzi, *Gazzetta Chimica Italiana*, in studying the reduction of potassium nitrate by various substances, has found that a mixture of equal parts of the nitrate and sodium hypophosphite detonates violently when heated to about the fusing point of the mixture. Other proportions yield explosive mixtures, but the above are the best. (*Sci. Am.* p. 181, March 19, 1887.)

H. N. Warren states in the *Chemical News* 55, 289, June 24, 1887, that he has probably obtained "Fluoride of Nitrogen" or fluoramide, by passing an electric current from seven ferric chloride batteries through a concentrated solution of ammonium fluoride. After a lapse of a short time, several drops, of oily consistence, were observed attached to the negative plate. On becoming connected with the positive, a thin gold wire, these drops exploded with great violence. The compound is undoubtedly highly unstable, being at once decomposed in contact with glass, silica, or organic matter, thus rendering the analysis one of considerable risk. Its explosive violence is even greater than that of the chloramide, and it is also prone to spontaneous decomposition.

There was recently a prosecution, before one of the Prussian courts, of the agent of a banking house in Berlin, for jeopardy caused to a train of railroad cars. The main question was whether fuming nitric acid could, under the circumstances, occasion spontaneous ignition,

which, after hearing the testimony of the court's expert chemist, Dr. Jeserich, was decided in the affirmative. The agent had sent ten kilos (22 pounds) of fuming nitric acid from Berlin, intended for some point in Bavaria, per railroad. The acid was contained in a strong stone jar, tightly closed by a stone stopper and cement. The whole was packed in straw within a wooden case. Since such corrosive and dangerous liquids would not be transported by railroad as express freight, the contents of the box were represented to be clothing, and by this means the concealed acid was sent by a passenger train. During the journey, and when near Butterfeld station, the car containing the express freight was discovered to be on fire.*

Before the flames had made serious progress, the car was uncoupled and switched off on a side track, and the fire extinguished with comparatively slight damage, and no person was injured. Examination showed that the jar had leaked, and the acid had come in contact with a roll of woolen cloth, whereby the latter was set on fire. Dr. Jeserich gave it as his opinion that all woolen goods and all hair of animals, horn, etc., have the property of igniting spontaneously when coming in contact with fuming nitric acid; and he stated that all new explosives, about which there had been so much said and written lately, such as roburite, melanite, etc., are produced by the action of nitric acid on hair and wool. Herr Lack, the agent who made the misrepresentation about the acid, was condemned to two months imprisonment. (*Sci. Am.* 57, 260; 1887, Abstr. *All. Vers. Presse*, Berlin.)

When preparing hypochlorous anhydride by the usual process, A. Mermet used liquid methyl chloride as a refrigerant instead of snow and salt. A violent explosion took place, the apparatus being destroyed and the assistant in charge had the lobe of his right ear torn. This catastrophe is ascribed to the vapors of the two liquids coming in contact. (*Chemical News* 55, 249, May 27, 1887, Abstr. *Bull. Soc. Chim.* 47, March 5, 1887.)

Scribner's Magazine, 2, 197-221, August 1887, contains an interesting article by N. S. Shaler on the "Instability of the Atmosphere," in which the destructive effects produced by a sudden rush of gas are well described, and illustrated by numerous photographs. In speaking of the tornado he says that in its path over the surface, the circling movement of the writhing air and the sucking action of the partial

* *Proc. Nav. Inst.* 8, 311; 1882, and 9, 753; 1883.

vacuum in the central portion of the shaft combine to bring about extreme devastation. On the outside of the whirl the air, which rushes in a circling path toward the vortex, overturns all movable objects, and in the centre these objects, if they are not too heavy, are sucked up as by a great air-pump. Thus the roofs of houses, bodies of men and animals, may be lifted to great elevations, until they are tossed by the tumultuous movements beyond the limits of the ascending currents and fall back upon the earth. Where the centre of the whirlwind passes over a building, the sudden decrease in the pressure of the outer air often causes the atmosphere which is contained within the walls suddenly to press against the sides of the structure, so that these sides are quickly driven outward as by a charge of gunpowder.

It is not unlikely that the diminution of pressure brought about by the passage of the interior of the whirl over a building may be about as much as is indicated by the fall of four inches in the barometer. This is equivalent to a change in the pressure amounting to about 300 pounds to the square foot. This force operates to burst out the walls of a building. It is not improbable that the diminution of pressure may be much greater than this, but the amount named is sufficient to produce many of the effects noted.

These effects may be compared with those produced by the discharge of heavy ordnance or the blasts from high explosives.*

G. Masson, Paris, announces, in June 1887, the publication of *Les nouveaux explosifs et la fortification*, by le commandant Mougin.

* Proc. Nav. Inst. 13, 408 ; 1887.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

FEBRUARY, 1888.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XVI.

Through the courtesy of Col. Majendie, C. B., H. M. Chief Inspector of Explosives, we are in receipt of a copy of his extremely interesting "Report on an Explosion at Roberts, Dale & Co's Chemical Works, near Manchester," which occurred June 22, 1887. This explosion was a very severe one, the local effect being as great as that produced by the explosion of $13\frac{1}{2}$ tons of gun-cotton in the great Stowmarket explosion of August 11, 1871, while the force was felt for a radius of two miles, and the sound was heard distinctly at a distance of twenty miles. The effect was more marked and widely extended than in the case of the Regent's Park explosion of 1874, when five tons of gunpowder exploded.

Inquiry revealed the fact that the company were large manufacturers of picric acid and of lead nitrate. The picric acid is made by melting carbolic acid and mixing it with strong sulphuric acid, then diluting the sulpho-carbolic (or "phenol-sulphuric") acid with water, and afterward running it slowly into a stone tank containing nitric acid. The mixture is allowed to cool, when the crude picric acid crystallizes out, the acid liquid (which contains practically no picric acid, but only sulphuric with some nitric acid) being poured down the drains. The crude picric acid, after being drained, is transferred

*As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. *Address Torpedo Station, Newport, R. I.*

to the boiling "stones," where it is dissolved in water by the aid of steam, and afterward allowed to cool, when most of the picric acid crystallizes out. The "mother liquor" is then transferred to the precipitating tank, in which the picric acid still left in solution is precipitated by the addition of sulphuric acid. The picric acid left in the boiling "stones" is once more dissolved in hot water, and this second solution transferred to the crystallizing tank, where it is left to cool, and where the picric acid crystallizes. These tanks generally contained about 130 lbs of picric acid. Finally the picric acid, after draining in the tank, is transferred to a centrifugal machine to remove the excess of moisture, and then dried on glazed earthenware trays in a steam-heated stove in which the temperature was not allowed to rise above 100° F.

The circumstances of the explosion were as follows: About seven or eight minutes before noon a fire broke out near the picric acid stove which spread with great rapidity over the works. After a lapse of about five or six minutes there was an explosion of a moderate character from somewhere about the stove, and a minute after this a second explosion occurred of a most tremendous and destructive character.

Investigation revealed the fact that before the fire there was in the immediate vicinity of the stove some 13 to 14 cwt. of picric acid, and a considerable quantity of litharge, of lead nitrate, and of strontium nitrate, any one of which would, when mixed with picric acid, according to the experiments made, form a detonating mixture; while not far off was a stone crystallizing vessel containing some 130 lbs. of picric acid crystals, probably wet; and that some few minutes before the fire broke out a man who had been smoking a pipe knocked the ashes out near the stove.

From a consideration of these and many other circumstances, Col. Majendie concludes:

1st. That the accident originated in a fire (either at or in the immediate vicinity of the stove), and that such fire was caused by the workman either in lighting, smoking, or "knocking out" his pipe.

2d. That the first or minor explosion probably occurred inside the stove, and whether due to the bursting of steam pipes, or to the explosion of some material present in the stove or formed in the course of the conflagration, was a direct result of the fire.

3d. That the second or main explosion was due to the detonation of a quantity of picric acid and self-formed picrate of lead (or other

detonative compound), and that this detonation effected the simultaneous detonation of the picric acid in the crystallizing vessel, the whole being the result of the fire.

In the course of this inquiry great differences of opinion were found to exist as to the explosiveness of picric acid ; the books stating it to be explosive by heat, while the various manufacturers claimed that it could not be exploded in this way even in large masses, and they supported their claim by citing instances where as many as five or six hundredweight, packed in bulk in a dry cask of light wood and exposed to fire, had burned away without explosion. The experiments made on this point by Sir F. Abel, Dr. Dupré, and Col. Majendie, gave results which supported the views of the manufacturers, yet Col. Majendie is not prepared to go so far as to assert that under no circumstances can unconfined picric acid be exploded by the action of fire.

There exists no doubt, however, that picric acid is liable to be exploded by detonation or by a blow, and that the picrates and the mixtures of picric acid with oxidizing agents are highly explosive. So far back as 1873 Sprengel remarked that "picric acid alone contains a sufficient amount of available oxygen to render it, without the help of foreign oxidisers, a powerful explosive when fired with a detonator. Its explosion is almost unaccompanied by smoke."*

Apart from this inquiry, the detonation of picric acid has recently attracted interest, from the alleged use by the French Government of this substance, in a particular fused and consolidated condition, as an explosive, under the name of *mélinite* ; and an English patent (No. 15,089, Dec. 8, 1885) has been taken out by Mr. A. M. Clark on behalf of M. Eugène Turpin of France, which claims the employment "as an explosive agent for military or other uses, of the trinitrophenol, or picric acid of commerce, unmixed with any oxidising substance," by the use of a powerful fulminating detonator, or by the use of an intermediate priming of picric acid in powder primed by the fulminate, or by dispensing with the fulminate and employing a sufficiently large charge of ordinary quick-burning powder enclosed in a strong tube and made to burst inside the charge of picric acid.

The explosiveness of picric acid by detonation and by a blow was also experimentally studied by the gentlemen above mentioned, and they find, 1st, that dry picric acid may be perfectly detonated by

* Jour. Chem. Soc. 9, 803 ; 1873.

means of a 5-grain fulminate detonator ; 2d, that the detonation of a small quantity of dry picric acid is capable of detonating a quantity of picric acid placed at a short distance from it ; and 3d, that the detonation of picric acid containing, at any rate, as much as about 17 per cent of water may be effected by detonating a charge of dry picric acid alongside it.

The experiments with blows showed that when thinly spread, dry powdered cold picric acid will be exploded by a weight of 54 pounds falling 20 feet, and may be by a weight of 1 pound falling 26 inches. The sensitiveness greatly increases with warming, so that when near its melting point (say 240° F.), a weight of 1 pound falling 14 inches will explode it. It was easily exploded in this state by the blow of a light hammer ($14\frac{1}{2}$ ounces with handle) on an anvil.

Mr. Peter van Brock, of Roslyn, N. Y., publishes in the *Mechanical News*, Nov. 15, 1887, a letter on the subject of firing dynamite from gunpowder guns, which he had addressed to Col. J. Hamilton, U. S. A., March 18, 1884, and to which he adds some further comments. He says : " Permit me to inform you and all interested, that dynamite has already been used as a shell-charge in the ordinary service-shells known as James, Hotchkiss, Rodman, and Parrott, and that with absolute safety and success in the years 1862, 1863, and 1865, the last official notice and firing having been granted by Gen. Ord, and the shell so loaded with chemically compressed dynamite fired from a 4.5 inch Rodman rifle, at Fort Powhatan on the James River, on or about the 20th of March, 1865. The officers in charge of the firing were a captain or major named King, and a chaplain in some regiment of the 24th Army Corps whose name I forget. I was the sole witness on the part of the inventor, but there were present at least one hundred officers and enlisted men. I can lay my hands speedily, if you want them, upon the three shells remaining from that trial ; the inventor will, I am sure, be glad to be rid of them, as they are fitted with Schenkl percussion fuse, with wood pins in place of brass, for more sudden explosion.

" And I have fired them myself from an old musket, .69 calibre, that is to say, brass shell containing 100 grains C. C. dynamite, said shell taking the rifling.

" As to the statement that dynamite always explodes downwards, that is another popular fallacy. All such explosives as nitro-glycerine, gun-cotton, and the fulminates in general, exert their force in

the direction of the greatest resistance. Dynamite exploded on top of a plank splits it to atoms; place it against a vertical plank and the same result follows, and if hung in a bag against the under side of a plank, you find the plank in fragments as before. Dynamite also operates best in close masses, not more than two diameters of the mass in length thereof.

“One of the shells of which I have spoken tore a hole in the side of an old hulk filled with cobblestones, big enough to drive a dirt cart through, clear. A 12-pound James shell, real weight 16 pounds, and containing only 12 ounces of this material, tore a hole in common rock (such as exists at Yorkville, New York City) big enough to hide a 42-gallon barrel in. Another of these last, exploding on the water, produced a pretty solid hailstorm, half a mile diameter. A 30-pound Parrott covered with its fragments a circle a mile in diameter—dynamite charge 19 ounces. Another, fired to penetrate a 6-inch iron plate, exploded there, making a hole big enough to run the muzzle of an 11-inch Dahlgren through. And judging by all I have seen done, there is not any vessel now afloat, with the sole exception of the Italian monster ironclads, that could remain afloat five seconds after receiving one dynamite shell from a 16-inch rifle.

“It is an absolute fact that no *pure explosive*, whether liquid or powder, can be used as a shell-charge in the front of such powder charges as are perfectly safe with powder shells. And yet I have seen the common shell explode prematurely, at or near the muzzle of the gun, and had them explode in the gun; but these accidents are the fault of the fuses, and not the charge. Moreover, one of these very dynamite shells broke up in the gun under my hand and went out like grape, and yet the compressed dynamite did not explode; if it had, this letter would not have been written. Another dynamiter exploded at a hundred yards from the muzzle, but the gun charge was so large that the fragments did not fly back.

“This time we were able to prove that the fuse was in fault, for it was found in a tell-tale condition, although tolerably well crushed up. These ill results led the inventor to construct a fuse that would always explode on meeting an obstruction, a piece of half-inch pine board, a foot square, hung by two strings, sufficing to work the fuse; or it could be changed in 15 seconds to pass through 6 inches iron and 30 inches spruce plank and explode behind them.

“The United States is not in the defenseless condition so harped upon by the papers endorsing Zalinski and his methods, which are

highly dangerous to the users if there were any enemy around. He cannot operate much over three miles, while our (common ordnance rifle) side can operate at from seven to twelve miles range, and our first cost is not a fiftieth of his, and fifty times more effective, while absolutely safe for the gunners.

“It will be observed that Graydon has used the same calibre that we last operated with, the 4½-inch siege gun—so he is 22 years behind-hand anyhow. Of course commercial dynamite can be used if it be not kept too long in the shell before firing, its safety against shock and friction being amply shown by Nobel’s first public experiments therewith. To have such shells explode on striking, without a fuse, means that they were left head downwards for a few days ; then enough pure nitro-glycerine would drain out of the dynamite to form a *percussion*, though not a *concussion* fuse.”

One naturally inquires when the dynamite used in 1862, 1863 and 1865, in the above described experiments, was invented, and we hence note here the statements of several well known authorities. Thus we find in *A Treatise on Explosive Compounds* by Henry S. Drinker (John Wiley & Sons), 1883, an extensive chronological table containing the most important events concerning explosives, and on page 55, in small capitals, to make it especially prominent, we find “1867—Nobel invented dynamite.” *Johnson’s New Universal Cyclopaedia*, Vol. I, Part II, 1882, contains an article on “Explosives,” written by Gen. H. L. Abbot, in which we find, page 1687, “Dynamite, called in the United States ‘giant powder,’ was invented in 1866–67 by Nobel.” In the article on “Explosives,” by Prof. Walter N. Hill, published in *A Naval Encyclopaedia* (L. R. Hamersly & Co.), 1881, we find on page 263, “In 1866 dynamite was brought out.” In the *Traité sur la Poudre et les Corps Explosifs* by E. Désortiaux, from the German of Upmann and Meyer (Dunod), 1878, we have Vol. 2, page 698, “Nobel fut encore le premier qui, vers la fin de 1866, parvint à la transformer en une masse solide et à l’introduire dans le commerce sous le nom de *dynamite*.” The *Handbuch der chemischen Technologie* by Drs. P. A. Bolley and K. Birnbaum (Friedrich Vieweg und Sohn), 1874, says in No. 23, page 66, “Nobel war wiederum der Erste, welcher gegen Ende des Jahres 1866, dasselbe in fester Gestalt als Dynamit in den Handel brachte.” *The Modern High Explosives*, by Manuel Eissler (John Wiley & Sons), 1884, states on page 39, “Dynamite was applied for the first time for blasting operations in the

year 1866." *On Modern Blasting Agents*, by Alfred Nobel (Maclehose and Macdougall), 1875, page 9, we learn that "It was then proposed and adopted as a temporary measure to render nitro-glycerine inexplusive, or rather much less sensitive, by adding methylic alcohol, in which it readily dissolves. On shaking it with water, which takes up the alcohol, the explosive properties are fully restored, and the same detonator cap, which has not the slightest effect on the mixture of nitro-glycerine and wood naphtha, explodes it after a moment's washing with water. That method of protection against the danger of nitro-glycerine, although much patronized by chemists, had many drawbacks, and was troublesome for miners to adopt. It was really never intended for general use, but only to serve until solidified nitro-glycerine, known under the name of 'dynamite' (in America, 'giant powder'), and invented already at an earlier date, could be adapted for practical use. That took some time, and the article was not put up for sale until about June, 1867." Finally, in *Sur la Force des Matières Explosives*, by M. Berthelot (Gauthier-Villars), 1883, Vol. 2, page 207, we find: "En 1866, à la suite d'accidents effroyables causés par des explosions de nitro-glycérine (Stockholm, Hambourg, Aspinwal, San Francisco, Quenast en Belgique), l'emploi de cette substance allait être partout interdit, lorsqu'un Suédois, M. Nobel, imagina de la rendre moins sensible aux chocs en la mélangeant avec une substance inerte, artifice bien connu pour atténuer les effets de la poudre ordinaire, mais qui conduit dans le cas actuel à des résultats inattendus. M. Nobel y ajouta d'abord un peu d'alcool méthylique; puis, cet expédient étant insuffisant, il le mêla avec la silice amorphe. Il designa ce mélange sous le nom de *dynamite*."

The *N. Y. Daily Graphic*, Jan. 23, 1888, describes with illustrations some experiments recently made by the Turkish Government at Agha Deressi, in firing explosive gelatine from gunpowder guns by means of the Snyder* projectiles. The piece consisted of a 15 cm. breech-loading rifled howitzer. The target, erected at a distance of 200 metres, was composed of twelve one-inch steel plates welded together and backed with oaken beams 12 by 14 inches thick. It was 4 feet 6 inches high, 14 feet 6 inches wide, and weighed altogether over twenty tons, including the massive frame of supporting beams in the rear. The shell was charged with ten pounds of the explosive, consisting of ninety-four per cent of nitro-glycerine and

* Proc. Nav. Inst. 12, 617; 1886, and 13, 411; 1887.

six per cent of a mixture of collodion gun-cotton, camphor, and ether. It is claimed that this explodes by mere percussion against a hard and solid body. The above described target was overthrown by a single shell. The photograph of the destroyed target probably does the experimenter an injustice, as from the position of the fallen target and the appearance of the backing it seems as if the support had not been sufficient for the weight of target put upon it.

The report of the army ordnance officers on the experiments made at Sandy Hook last December in firing dynamite shells from a rifled gun and with the regular powder charge has been made public. The Board consisted of Lieutenant-Colonel A. Mordecai, Major J. P. Farley, and Captain John E. Greer. In their report to General Benét, Chief of Ordnance of the United States Army, they say the testing target was totally wrecked. It was a wrought-iron semi-circular turret, eighteen feet wide, ten feet high and fourteen inches thick, made of two seven-inch plates closely assembled and riveted together with heavy bolts. The damage and disruption were done by three dynamite shells fired from a seven-inch Ames rifled gun. The shells were of steel, weighed 122 pounds, and were charged with two and two-thirds pounds of dynamite. Three demonstrations of this invention have thus far been made by order of General Sheridan—two at San Francisco, in the summer of 1886, and the third at Sandy Hook. The experiments at San Francisco were conducted by General O. O. Howard, and were intended merely to demonstrate that shells charged with dynamite could be fired from cannon without premature explosion. After fifty-eight dynamite shells had been successfully fired out of a three-inch and four and one-half inch siege gun from the Presidio grounds into the hills across the Golden Gate, the board of officers conducting the experiment expressed the opinion in their report that the two principal causes—apprehensions of danger from heat and shock—had been completely guarded against. General Howard then recommended further experiments with larger guns, and out of this recommendation grew the Sandy Hook demonstration with a seven-inch Ames gun and 122-pound shells. The San Francisco experiments had proven that dynamite shells could be fired from cannon with safety, and at Sandy Hook it was intended to prove that dynamite shells possessed still another important merit—that of obtaining penetration before explosion.

The effect of the three shots fired there is minutely described by

the Board in their report. The first shell which struck the target was a glancing shot, and not a "point on" shot, as was desired to test the penetration. It made an indenture, nevertheless, three inches deep, exploding with great violence. The Board says:

"The roof of the turret, weighing 30,900 pounds, was lifted off and blown twenty-five feet to the rear, breaking seven bolts, each one and three-fourths inches in diameter, used to assemble the same, and five bolts three and three-fourths inches in diameter used to bolt the front and rear plates together. It also made a crack ten inches long in the front plate and about eighteen inches long in the rear plate. The wreckage was very marked. The two seven-inch plates of the turret proper were also torn apart a distance of five inches, breaking off the bolt heads which secured the plates together."

The result of the second shot, as stated in the report, was as follows:

"The shot struck in a mark one inch deep that had been made by an empty cast-iron shell, deepening the impression to three and one-eighth inches sixteen inches below the first shot. It continued the crack made by the first shot upward to the top bolt holes and downward to the horizontal joint, the length of this crack being five feet two inches. This was also a glancing shot, the same as the first."

The wreckage produced by this shot was even greater than that of the first, the two seven-inch plates forming the turret proper, which were torn apart by the first shot, being torn still further apart to the extent of seven inches. Numerous bolts were also broken and displaced, and the rear plate cracked from the embrasure to the bottom of the turret.

The third shot penetrated the first plate seven inches and the second plate one inch. The front plate was broken, a piece two feet eleven inches by three feet three inches being thrown eighteen feet to the left of the target. The cracks in the rear plate were opened, five new cracks made about nine inches long, and the plate opposite the point struck bulged out to the rear three inches. The shot completely destroyed the left side of the target, the penetration of the front plate being effected before the explosion of the dynamite, and its wrecking energies being entirely exerted on the turret. The weight of the piece blown out was variously estimated at from one and a half to two tons. The two main seven-inch plates composing the turret were also still further separated and numbers of bolts blown off.

At this point it was deemed useless to fire any more at the wrecked turret, the section of the target fired at having been virtually destroyed

by three ordinary steel shells filled with less than three pounds of dynamite.

The main points of merit thus substantiated were :

1. To fire a dynamite shell from a heavy rifled cannon with the full service charge of black powder as the propelling force without injury to the cannon.

2. To obtain full penetration* by the shell before the dynamite was exploded in the target.

Four other shells were fired on this occasion at different ranges, one reaching the full range of the cannon, estimated at four and a half miles, out to sea.

Other experiments with the largest guns in the service, and with twelve-inch rifled mortars throwing 625-pound shells a distance of five and a half miles, and with the Hotchkiss revolving cannon, will soon be made to still further test the merits of this method of charging shells with dynamite.—*New York Herald*, February 6, 1888.

In the "Story of the Assassination of Alexander II," by J. E. Mud-dock, after describing the organization for this purpose and speculating as to why the special method used was selected, he says: "But this much is certain: a student in the School of Chemistry at St. Petersburg sent to the committee in Paris a formula for the preparation of an explosive compound. This compound, while having glycerine as a base, was not what is commonly known as nitro-glycerine, but was infinitely more powerful than even that powerful explosive. It was stated that so small a quantity as two drachms, confined in a steel tube, would, on being exploded, kill every living thing within a radius of twelve yards. What became of the inventor of it is not accurately known, but he is supposed to have drowned himself in the Neva. The reason the explosive was not prepared in Russia was owing to the difficulties there were in the way of procuring the ingredients without arousing suspicion. The bombs themselves, however, were manufactured in St. Petersburg. And this important work was placed in the hands of one Keebalchich, the son of a priest. This man had studied for the Church, but had subsequently entered the School of Government Engineers."

He displayed much ingenuity in making these bombs, which "were conical in shape; the conical end being so weighted that, on falling, that part of the bomb was sure to strike the ground first. In the

* *Proc. Nav. Inst.* **11**, 291; 1885.

extreme tip of the shell, and also in a circle round the end, percussion caps were sunk. These in turn communicated with a slender steel tube that extended from tip to base of the shell. This tube was filled with the explosive to which allusion has been made. It was a clear amber-colored fluid, but thick like golden syrup, and sweet to the taste. A few moments, however, after it had touched the tongue, a painful, burning sensation was experienced. If two or three drops of this stuff were allowed to fall upon a hot stove they instantaneously produced an enormous and blinding sheet of brilliantly white flame. But there was neither noise nor smoke, though a peculiar odor was evolved that resembled that of burning leather. Round the steel tube blasting powder was rammed very tightly, and between the powder and the wall of the shell was a thin layer of gun-cotton. At least half a dozen of these formidable engines of death were manufactured, together with some of a more ordinary kind, while two were made of glass filled with dynamite."

The fatal bomb, thrown by Elinkoff, the conspirator, who was only a few yards away, "fell at the Czar's feet, but, strangely enough, though the force of the explosion was tremendous, men who were standing many yards away being knocked down by it, while a huge hole was ploughed in the ground, the Emperor was not killed outright, but both he and his assassin fell to the ground terribly injured. Elinkoff died very soon afterwards, but his Majesty lingered in dreadful agony for several hours. His lower limbs and part of the abdomen were torn and shattered to pieces."—*Littell's Living Age*, 61 [5], 301-306; 1888, from *The Gentleman's Magazine*.

Prof. Watson Smith, F. C. S., F. I. C., has kindly supplied us with a copy of his address "On Kinetite," reprinted from *Jour. Soc. Chem. Ind.* 6, 2-12, 1887. This substance, which was invented by Messrs. T. Petry, O. Fallenstein, and H. Lisch, of Düren, is prepared by dissolving gun-cotton, or other cellulose nitrate, in the nitro-compound of an aromatic hydrocarbon—for example, nitrobenzene—and then they knead potassium chlorate and nitrate, ammonium nitrate and similar compounds, with the resulting jelly, and finally three per cent of antimony pentasulphide is added to the whole and well incorporated. High power, great stability, and cheapness are claimed for this explosive, and the reports of many excellent chemists are cited in support of these claims. The English Inspectors of Explosives are, however, not yet satisfied as regards its security in use and storage. The address was accompanied with illustrative experiments.

Another explosive, called petrofracteur, is described in the foregoing paper. It is composed of nitrobenzene ten per cent, potassium chlorate sixty-seven per cent, potassium nitrate twenty per cent, and antimony pentasulphide three per cent.

At a recent meeting of the Royal Society of Edinburgh, Professor Tait made some interesting and suggestive remarks on "The Effect of Explosives." The singular fact had been stated that an explosion of dynamite in the Underground Railway in London produced the curious effect that some persons within a certain range had the drum of one ear ruptured while no effect was produced on the drum of the other ear. If he had not been thinking for years about the effect of lightning flashes upon the air he must have set this down to newspaper reporting. The effects of a sudden explosion in the immediate neighborhood of the centre at which the explosion took place, and the effects of the same at a moderate distance, might be perfectly different from one another; and when examination was made of the matter from the physical point of view, it was found that the difference depended on this: that as long as the projectile matter—whether it was the air itself around the explosive, or the materials of the explosive which were driving it from the centre of the explosion—were going at a velocity greater than sound, the effect of their motion was precisely the same sort of thing as is observable in the case of a falling star. It compressed and immensely heated the air immediately in front. So long as it exceeded the velocity of sound there could be no vibrations propagated beyond the limit to which the explosion had extended, and the gases only came, as it were, into contact with a dead stone wall of stationary air outside. The result was that the air was compressed and became self-luminous by the instantaneous compression. So it was with lightning. Up to the point at which the velocity became that of sound there would be an exceedingly intense impulsive pressure, and there was great danger of very considerable damage. The question of how much force was required to rupture the drum of the ear was a question for physiologists. Being asked by Dr. Wallace how it was that for explosive purposes gunpowder required to be inserted into the material to be exploded while dynamite was placed on the top, Professor Tait replied that dynamite exploded with great rapidity, and the consequence was that the gases expanded with exceeding rapidity, whereas gunpowder was burned comparatively slowly and produced the effects

of increased pressure with graduated speed. If the velocity was much greater than that of sound there was percussion, otherwise there was nothing but the propagation of vibration. It was the difference between a wave and a breaker.—*Engineering*, 43, 577; June 17, 1887.

Smoke will certainly play an important part in the warfare of the future. Last year at Milford Haven, and this year in Langstone Harbor, it was artificially created in large quantities in order to form screens behind which attacking forces might, unobserved, approach within range of forts and batteries. On each occasion rafts laden with combustibles were set on fire and floated into positions from which the wind carried the smoke in a more or less dense cloud in the direction of the defense. On the other hand, ever since the introduction of modern ordnance and rapid rifle fire, it has been felt that the huge volumes of smoke which would be belched forth during a battle of the present day would probably prevent the use of big guns to the best advantage. Smoke, in fact, may, according to circumstances, be either a great assistance or a grave impediment in warfare. The ideal state of things is, of course, one in which the production of smoke shall be controlled, so that either a clear atmosphere or a clouded one may, as need may arise, be created around a battery or ship in action. This ideal has now to some extent been attained. It is found that smoke, as it issues from the muzzle of a heavy gun, can be almost instantaneously precipitated by means of a simple electrical apparatus. The invention is based upon the researches of Prof. Tyndall, Lord Rayleigh, and Prof. Lodge on the action of electricity upon floating dust and vapor, and it should be of considerable military value.—*Boston Herald*, Dec. 18, 1887.

F. Nettlefold has sought to ascertain "The Influence of Nitrate of Soda on Gun-cotton," meaning thereby the effect due to the hygroscopic property of this salt. He made primers of uniform size containing (1) lime in small quantity, as required by the Government, and 30 per cent KNO_3 ; (2) lime and 30 per cent NaNO_3 ; (3) 30 per cent of NaNO_3 only; the variation in lime being made since it had been suggested that lime might, by conversion into nitrate, act as the absorbent. The substances were exposed in damp places for varying periods and the change in weight noticed. The data obtained is given, but in such form that it is difficult to ascertain what conclusion is to be drawn from it.—*Chem. News*, 55, 241; May 27, 1887.

F. Nettlefold, F. C. S., discusses in the *Chem. News*, 55, 306; 1887, the "Nitration of Cellulose," a subject which assumes greater importance as the production of the lower nitro-celluloses for use in powder and for pyroxylin increases, and which is also of importance in connection with the manufacture of military gun-cotton. It will be readily understood that the thin wall tubes of cotton fibres are readily penetrated by the mixed acids, and consequently the highest state of nitration results. In the case of ligneous tissue the cells have been thickened by matter from the sap and almost blocked up. This thick wall is not so readily penetrated, and so only lower nitro-bodies can be obtained.

Thus with clean cotton, using a mixture of 33.3 per cent nitric acid 1.506 sp. gr., of 94 per cent HNO_3 and 66.7 per cent H_2SO_4 , sp. gr. 1.840, a near approach to trinitro-cellulose is attained—a product with a solubility of 7 to 9 per cent, having a proportion of nitrogen 13.94 to 13.86 per cent, against a theoretical proportion of 14.14 per cent N in pure trinitro-cellulose, when 0.85 per cent is deducted for ash.

Since so large a quantity of wood pulp is used in the manufacture of powder, such as the Schultze, it may be interesting to consider the few following experiments to show what definite result arises in nitrating these different bodies, though often described—in the case of wood—as consisting of vasculose, para-cellulose, and fibrose.

Beech wood and fir wood are not easily nitrated, on account of the unstable compounds they form. In the case of a fine sample of white pine flour, named O in commerce, a dark, ochre-colored product was obtained with 41.6 per cent soluble in a mixture of 2 parts absolute ether, 1 part alcohol, 58.4 per cent insoluble in alcohol. The total nitrogen in this was 11.2 per cent. Taking the soluble portion as being dinitro-cellulose, the insoluble remainder would have a proportion of 11.3 per cent nitrogen, or a rather higher state of nitration.

A sample of wood pulp gave also 11.2 per cent N. The resinous matter was extracted by boiling in caustic soda, and the washed residual fibre was nitrated, yielding 11.57 per cent N. This proportion of nitrogen would indicate that the product lay between dinitro-cellulose and the formula given by some authors as $\text{C}_{24}\text{H}_{37}(\text{NO}_2)_9\text{O}_{20}$, with 11.9 per cent. It might be conceived at first sight that the insoluble portion consisted of a mixture of trinitro-cellulose and unnitrated fibre, but as a matter of fact woody tissue is not readily brought to this high state of nitration.

The existence of these more complicated nitro-bodies, with four times the formula $C_6H_{10}O_5$, is further seen in the following instance: Cotton was nitrated in weak acid, yielding a product 33.0 per cent soluble in the mixture of ether and alcohol, 63.5 per cent soluble in acetic ether, 3.5 per cent insoluble. Taking the 33 per cent as dinitro-cellulose, containing 11.1 per cent N, the 63.5 per cent would have 10.1 per cent; analysis gave 10 per cent. The formula $C_{24}H_{33}(NO_2)_7O_{20}$ has 10.17 for theory.

With	25 per cent nitric acid	}	10.47 per cent N,
75	" " H_2SO_4		
	20 " " nitric acid	}	8.23 per cent N,
	80 " " H_2SO_4		

the latter product might be near to the $C_{24}H_{35}(NO_2)_5O_{20}$, with 8.02 per cent N.

With the mixture of strong acids, 33.3 HNO_3 , 66.7 H_2SO_4 , and various quantities of water, ranging from 10 to 15 per cent, to form collodions, products ranging from 10 to 11.1 per cent nitrogen are obtained; these are all soluble in acetic ether, and are probably homogeneous chemical products.

In the Schultze powder the nitrated wood fibre has 10.44 per cent N, lying between $C_{24}H_{33}(NO_2)_7O_{20}$ and $C_{24}H_{32}(NO_2)_8O_{20}$, or between 11.1 and 10.17 per cent. But in order to obtain this in the case of cotton a dilute acid is required, whereas in the case of wood fibre the strongest has to be taken.

C. Loring Jackson and John F. Wing found that when the symmetrical trichlorobenzene was treated with fuming nitric acid (sp. gr. 1.505) in the cold, trichlordinitrobenzene was formed, and to obtain the trichlormononitrobenzene it was necessary to dilute their acid to 1.46, whereas Beilstein and Kurbatow state that only the trichlormononitrobenzene results from the action of fuming nitric acid in the cold, even when the latter has a sp. gr. of 1.52. To discover the cause of this discrepancy the authors have studied the "action of nitric acid on symmetrical trichlorobenzene," and also on the tribrom compound, and they find the cause to lie in the fact that the nitric acid of specific gravity 1.505–1.51, prepared at the Cambridge laboratory, is much more efficient in its action than the commercial fuming nitric acid used in the laboratories of St. Petersburg (1.52), Berlin and Munich (1.534); and they are inclined to ascribe the high specific gravities of these commercial acids in part to the presence of

lower oxides of nitrogen, while the specific gravity of the Cambridge acid was due probably exclusively to HNO_3 , since it was prepared direct from nitre and sulphuric acid without pushing the reaction beyond the formation of the hydrogen potassium sulphate. This explanation was based upon the observation of Kolb* that the specific gravity of nitric acid is raised by the solution of nitrogen tetroxide in it; and although it was not feasible to submit it to direct experimental proof, since commercial fuming nitric acid was not to be had in this country, yet the examination of a nitric acid similar to that used in foreign laboratories makes it exceedingly probable that this explanation is correct. This acid was prepared by distilling common nitric acid twice with an excess of sulphuric acid; it had a decided yellow color, and a specific gravity of 1.535 at 15° (the temperature at which all these determinations were made), but converted tribromobenzene into tribromonitrobenzene only when acting in the cold, although it gave the dinitro compound when boiled with it. It was therefore less efficient than the Cambridge acid of sp. gr. 1.51, but more so than the foreign acids mentioned above. The analysis of these two acids gave the following results:

	Percent NO_2 .	Percent HNO_3 .	H_2O by difference.
Acid of 1.535 sp. gr.	5.0	93.38	1.62
“ “ 1.510 “ “	0.5	96.92	3.58

The nitrogen tetroxide was determined in the usual way by treatment of the diluted acid with a standard solution of potassium permanganate. The results are not absolutely accurate, according to Feldhaus,† because of the loss of nitrogen tetroxide in transferring the acid from the weighing or measuring tube to the beaker, but are nearly enough so for this purpose. The nitric acid was determined by neutralization with ammonium hydroxide and weighing the ammonium nitrate dried at 120° . It contained no ammonium nitrite. The estimated amount of nitric acid, corresponding to the nitrogen tetroxide found, has been subtracted, so that the number given represents the percentage of free HNO_3 in the acid.

The number representing the free HNO_3 for the second acid is higher than that given by Kolb as corresponding to this specific gravity (1.51), which is 94 per cent. The difference may be due to the presence of amines in the ammonia used, but the authors did not

* Ann. Chim. Phys. **10**, [4], 137. Kolb's table is given in Watts' Dict. Chem. **6**, 866.

† Zeitschrift für anal. Chemie, **1**, 426.

study this point, since they were not interested in the absolute determination of the HNO_3 in the acid, but only in the relative amounts in these two acids, and these are given accurately by the numbers, since they were obtained under exactly parallel conditions.

These results show that the acid with the higher specific gravity contains the smaller amount of HNO_3 , and therefore that the determination of the specific gravity is not a trustworthy way of finding the strength of nitric acid, unless the sample examined is free from the lower oxides of nitrogen.—*Am. Chem. Jour.* 9, 348-351; 1887.

From the *Oil, Paint and Drug Reporter* of Jan. 4, 1888, we learn that during the previous week an explosion occurred in the drug and spice mills of McIlvain Brothers, at Fifteenth and Hamilton Streets, Philadelphia, which destroyed several windows and seriously injured the workman in charge of the mill, who was severely burned about the face, neck, and arms. The cause of the explosion is not known, but is thought to have been due to improper material having been sent to the mill to be ground.

“The Explosion at Amoy” is described by Miss Gordon-Cumming in the *St. James's Gazette*, and from this we learn that the magazine at the time of the explosion contained 40,000 kilos (88,000 lbs.) of gunpowder. As a result of the explosion, fifty soldiers were blown to atoms, several hundred other persons were killed, and a multitude grievously injured. All the buildings on the side of the town where the magazine was were shattered, and as houses fell fire was scattered. A great conflagration speedily ensued, rapidly spreading till it extended over a fourth of the whole area of the town. The island of Ku-long-su, which is the place of residence for foreigners, and which is separated from the island of Amoy by a narrow strait, was rocked as if convulsed by an earthquake, and several houses fell in ruins. The city of Amoy contained a population of upwards of 100,000 Chinamen, and the island of Amoy, which is about ten miles in diameter, contained an estimated population of about 250,000.

From the daily papers of Rochester, N. Y., we learn that a very serious explosion occurred in that city December 21, 1887, by which three men were killed and twenty seriously injured, while three large flour mills were knocked down and then set on fire, besides which the streets were badly torn up; the estimated loss being about \$250,000.

Investigation showed that the explosion was caused by the ignition of vapor of naphtha, which found its way in enormous quantities into the sewers, mixed with air, and that this naphtha had escaped from an underground pipe line which was used for conveying the naphtha across the city from the Vacuum Oil Company's Works to the Municipal Gas Works. Some 14,000 to 15,000 gallons of naphtha were pumped on this day from the Vacuum Oil Co's Works, none of which was received at the Municipal Gas Works, so that this amount was involved in the conflagration and explosion. It is supposed that the vapor was ignited by the fire under a boiler in a cellar on Platt Street, but of course there must have been many opportunities for ignition. The coroner's jury found the Vacuum Oil Co. responsible for the disaster, but we learn that both companies have been indicted.

This explosion originated from the same cause as the one which occurred in Pawtucket, R. I., July 19, 1886, a full account of which may be found in the *Providence Journal* of July 19, the damage done in this case being confined to tearing up the roadway, breaking window panes, demolishing some slight structures, and injuring some of the bystanders. It is noted as a curious feature of this explosion that in every case the glass from the windows was thrown into the street instead of into the buildings. We understand that the responsibility for this accident is yet before the courts for decision.

Prof. C. A. Young, of Princeton College, describes a "curious explosion" which occurred there while filling a cylinder with oxygen. The cylinder was a forty-foot one of steel, made to stand a pressure of fifteen atmospheres, and had been used at that pressure for a year or two. At the time of the explosion the pressure was only about ninety pounds. The oxygen was being pumped into the cylinder from the gas holder by an ordinary force pump driven by steam and making about eighty strokes a minute. The lower portion of the cylinder was immersed in water to keep it cool, and the pump piston was lubricated with a heavy mineral oil such as is used in steam engine cylinders. The seat of the lower valve was of hard rubber, and had just been faced off, so that the pump was in exceptionally good order and working very effectively. The connection between the pump and cylinder was by a heavy lead pipe of about a quarter-inch bore and five feet long. Two persons were in attendance; one, the mechanic, stood by the pump watching the pressure

gauge, the other, his assistant, stood by the cylinder. Suddenly a flame, blue or green, and some three or four inches long, made its appearance on the top of the cylinder where the lead pipe was coupled to the stop-cock. The assistant sought to turn the wrench to prevent the loss of gas, but before he could do so the explosion occurred. The cylinder was torn in two about six inches from the bottom, the upper part striking the floor above, and the glazing and plastering of the room was much damaged. The mechanic had his eyebrows singed, and a piece of metal as large as one's hand shot through the brim of his hat; the assistant was thrown nearly twenty feet against the gas holder and was a good deal bruised and shaken, but not seriously injured. Somewhat similar explosions have occurred at Princeton before in charging the oxygen cylinder, but none so severe, and they are said to happen in establishments which deal with gases on a large scale.

The inside of the cylinder, in the explosion above described, was found to be covered with a film of oil which came from the pump cylinder, a little puff of gas and oil spray passing through the valve at each stroke of the piston. Hence Professor Young concludes that the explosion was due to the firing of oil spray, and possibly a little oil vapor, mixed with the oxygen gas, and that the firing was caused by the sudden pressure produced at the lower valve of the pump by each piston stroke.

To prevent these explosions he recommends that soapsuds be used as a lubricant in place of oil.—*Scientific American*, p. 369, June 11, 1887, from *Popular Science News*.

Explosions during the preparation of oxygen have repeatedly occurred in the past. One which happened at Cannes in 1880 attracted considerable attention from the factitious circumstance that it was being prepared for the Empress of Russia. In this case, according to the *Répertoire de Pharmacie*, it was held by M. S. Limousin to be due to particles of incandescent potassium perchlorate being driven over into the rubber tube and generating hydrocarbons, which formed an explosive mixture with the oxygen. In this case potassium chlorate *per se* was being used, and it is not uncommon that when the violent ebullition takes place, sparks are seen rushing through the water of the interposed washing flask. The gas then appears to force its way through the water in such a manner that the central portions do not come in contact with the liquid. Explosions

from accidental admixture of antimony sulphide and combustible matters have not been infrequent.

The *Revue Scientifique*, pp. 262-272, Feb. 26, 1887, contains a very readable article by M. Favier on the "Explosives of the Future," in which, after describing and classifying the explosives now in use and considering their methods of formation and decomposition, he arrives at the conclusion that we must abandon the organic nitrates and nitro-substitution compounds as too sensitive for use, at least for military purposes, and that the explosives of the future will be mechanical mixtures. He gives results with several such mixtures, which appear nearly as powerful as, or more powerful than nitro-glycerine, but no hint whatever is given as to their composition.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH,

APRIL, 1888.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XVII.

We are in receipt of a pamphlet entitled "The Graydon Dynamite Projectile High Explosive and Accelerated Cartridge," from which we learn that the experiments made at Sandy Hook, which were described in No. XVI of these Notes,[†] were carried out under the Graydon system.[‡] The pamphlet contains three cuts showing the target before and after the experiments and one of the shells which struck "point on." The target, according to the cut, was a section of a monitor turret in service condition, lacking only the support which the completed cylinder gives. We should judge from the appearance of the shell, if the artist has represented it correctly, that the explosive did not undergo complete detonation.

Captain Zalinski having criticised the results of these experiments adversely, he was met by a letter from W. W. Dudley, general manager of the Graydon Dynamite Company, which was published in the *Washington Post* of February 27, 1888, and in which exceptions were taken to some of Zalinski's alleged statements. Captain Zalinski's reply to this appears in the *Washington Capital* of March 4, 1888, and the *New York Herald* of the same date. We have not

* As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. *Address Torpedo Station, Newport, R. I.*

[†] *Proc. Nav. Inst.* 14, 156-158; 1888.

[‡] *Ibid.* 13, 412-413; 1887.

seen the first two statements, but have been supplied with copies of the last two. In the *Capital* Captain Zalinski says :

“The Graydon system has thrown but very small charges of high explosives, and cannot throw very much larger ones successfully, ‘with full powder charges.’ It can hardly, therefore, be considered in the same category as the Pneumatic Torpedo Gun system, which has already thrown shell containing 100-pound charges of explosive gelatine and dynamite No. 1, and will, within a very few weeks, throw charges of 600 pounds.

“But as a proof of the substantial correctness of my statements, the following is given as a summary of the *last* Graydon experiments at Sandy Hook.

“Experimental firing with shells charged with dynamite by Graydon’s method were made by the Ordnance Board, U. S. A., at Sandy Hook, on December 1, 1887, under supervision of Mr. Graydon, to obtain penetration of armor. A delayed action percussion fuze was used. Seven shots were fired from a 7-inch M. L. rifle; weight of charge 23 pounds, weight of loaded shell 122 pounds, weight of dynamite in shell about $2\frac{1}{4}$ pounds. The target was a section of a wrought iron turret 14 inches thick, composed of two 7-inch layers which had been considerably damaged in former experiments. It was placed 100 yards from the gun. The first shot fired, without fuze, exploded violently upon striking target. All the other shells were provided with fuzes; the second deepened the indentation about 2 inches, and the third about 4 inches. The fourth and fifth shots were fired at a wooden target about a mile distant; the fourth burst prematurely in the air, the fifth burst upon striking. The sixth and seventh shots were fired at sea; the flight of the sixth was very irregular, it probably failed to take the grooves. It did not burst upon striking the water. The seventh burst prematurely in the air. To demonstrate the safety in handling shots were fired from a Springfield rifle at a can filled with the prepared dynamite. It blew up at the third shot.

“In the experiments preceding the ones of which very partial and incomplete extracts of the board are given in Graydon’s pamphlet, a gun *was burst* in the attempt to fire one of the Graydon shells. This can be substantiated by reference to official reports. There is also quite authentic information that at *least* one gun has been burst by Graydon in European experiments.

“It will be noted that in all the quotations made from reports of

boards no mention is made of the fact that a gun had been burst at Sandy Hook. This may, however, appear to be a very trifling matter. It may be well to analyze the recent Sandy Hook experiments, upon which so much stress is laid, and see what has been accomplished. The weight of shell thrown was 122 pounds. The charge of dynamite claimed was $2\frac{2}{3}$ pounds. There is reason to suppose that the charge of *dynamite* was really less, but it is too small a matter to discuss further. But the dynamite thrown was only a 60 per cent dynamite. Now, in speaking of dynamite for military purposes, No. 1 dynamite, containing 75 per cent of nitro-glycerine, is supposed to be referred to. The 60 per cent dynamite is less effective by 20 per cent than the No. 1 dynamite, and also much less sensitive to shock. Being tested in cold weather (December), may also be a factor to consider, in view of the ease with which it congeals, and its reduced sensitiveness and efficacy when in a congealed state. This charge of $2\frac{2}{3}$ pounds is a trifle more than 2 per cent of the total weight of the shell. Whatever its effect might be if the shell had really penetrated armor, its effect would certainly be nil as a *torpedo*. On the other hand, the shell of the Pneumatic Torpedo Gun carries a charge of the highest grade of high explosives of from 60 per cent to 200 per cent of the weight of the shell. In other words, the charges its shell will convey are from 100 pounds up to 600 pounds of explosive gelatine. Comparing simply the charges actually thrown, we have a record of shells fired carrying a charge of 100 pounds of explosive gelatine, equivalent to at least 166 pounds of Mr. Graydon's 60 per cent dynamite, or more than sixty times as much. The larger charges thrown by the Pneumatic Torpedo Gun must be effective for torpedo action against the under-water hull, and this is the main point claimed. But, if properly exploded, they will not be innocuous when striking the over-water hull.

"It is obvious that Mr. Graydon has done nothing to approach this, and cannot, therefore, claim to come within the same field. The full official reports will show that several of the Graydon shells *did* burst near the muzzle and some distance therefrom *whilst in the air*. Let us now examine the claims as to penetration of the target and the character of the injuries done thereto. The target, as stated by Graydon, consisted of two layers of 7-inch wrought iron plates bolted together. This is very far, in its resisting capabilities, from a 14-inch plate. The illustrated pamphlet, published also by Graydon, shows that these, which were bent in a semicircular form, simply stood,

unsupported at front or rear, on some planking. They weighed, at most, 120 tons. The Graydon shell, weighing 122 pounds, if fired 'with full powder charges,' should have attained a velocity of not less than 1300 feet per second. This should give an energy of at least 1400 tons. The 7-inch shell, *without any bursting charge*, should have obtained a *penetration* of at *least nine* inches. The utmost penetration shown by the official report is only *eight* inches, and this penetration was produced by hitting in a spot where, at some previous experiments, the target had been indented from one to *three* inches. It may be well to state here that this same target had been very considerably injured by firing of shell other than the Graydon in previous experiments.

"The *penetration* produced, it is seen, is less than that due to a blank shell. As the target weighed only 120 tons and was totally unsupported against a blow of 1400 foot tons of energy, due to the shell, unaided by the explosive, it would have been very easily racked and shaken up by the first round, so that the bolts assembling the various plates would have been disrupted and the plates separated. They would not, in this condition, present much more resistance than that due to a *single unsupported 7-inch* plate. It is to be noted, also, that this plate has numerous very large bolt holes in it, which would not exist in modern armor plates; these would determine lines of weakness in the plates already well battered by previous fires.

"The shells used were probably not less than $2\frac{1}{2}$ calibers long, and therefore about 17 inches in length. The maximum penetration *claimed* was only 8 inches. It will thus be seen that hardly more than the ogival point of the shell had entered the plate before explosion, and thus the explosion had taken place practically *outside* of the target. 'Penetration before explosion' can hardly be substantiated by these results, even when a portion of the indentation had not been made at a *previous* fire. Especially is this the case in view of the fact that the *blank* shell would have produced a *greater* indentation than was actually claimed for the *loaded* shell.

"The racking effect of a blow of 1400 foot tons of energy on an unsupported iron target, weighing only 120 tons, would easily snap the $1\frac{1}{4}$ -inch bolts by which the top or cover plates were attached to the vertical target. The explosion of the charge ensuing probably *after* this blow had been delivered might very readily shake and lift this, weighing only 15 tons, and deposit it a few feet from the vertical

target, particularly as it is seen, from the illustrated Graydon pamphlet, that there was a marked over-hang of the turret cover.

"I will concede that a shell charged with high explosives will, in itself, produce but little injury to an iron target, unless properly exploded from the rear end, and not by simple impact. Although Graydon claimed that no explosion would ensue if his shell did not carry his fuze, explosion *did* take place in his first fire, where the shell *was* unfuzed.

"I should be pleased to think that a charge of $2\frac{1}{2}$ pounds of 60 per cent dynamite could really perform the injury to a well supported target when exploding, as did the Graydon shell, on the unsupported target practically outside of the plates; I should feel more sanguine than ever of the results which a 600-pound charge of camphorated explosive gelatine would produce on striking even the heaviest armor, although this is not the objective target of the pneumatic torpedo shell.

"To summarize: The official report will show that Graydon had burst at least one gun at Sandy Hook; that he had *not penetrated* with his shell, *before explosion*, to an extent as great as would have been accomplished with a blank shell; that the injury done to the unsupported and already injured target was but little more than would have been accomplished by any equal number of rounds with similar powder gun shell; that *several* Graydon shell *did burst prematurely in the air without impact on any target*; that the percentage of the weight of high explosive thrown is insignificant when compared with the total weight of the projectile; that the sum total of the results obtained would certainly not encourage the Ordnance Department of the Army or Navy to permit the Graydon shells to be fired from their best modern high-power guns, which alone can give requisite penetration, pure and simple, against modern armor. Neither would the results as to *safety* warrant the gunners standing by the guns when fired, or make it permissible to fire these shells over the heads of troops or outlying works of the defense.

"The questions raised regarding the report of the Naval Board on the Pneumatic Torpedo Gun may be discussed at some future time and before the proper authorities.

"Very much is conceded therein without qualification, particularly as to its accuracy, safety, and applicability in harbor defense. Personally, I desire nothing better than to be able, when the Pneumatic Dynamite Torpedo Gunboat is completed, to attack an armored

vessel, of the strongest construction that modern ingenuity can give both to the under-water and over-water hull.

“For purposes of comparison of the relative *chances* of hitting, and of *efficiency* when hitting, I would have, at the same time, an attack on the target by ships carrying high-power powder guns and using Graydon’s shells (if they will dare to use them) or any other kind of shells, and by torpedo boats carrying Whitehead, Howell or any other kind of torpedoes. Such a trial should simulate service conditions as nearly as possible, the attacking force at least to be in motion at full speed. If the sea is rough, so much more thoroughly will be the question of the relative *chances* of obtaining results be settled.

“The efficiency of the Pneumatic Torpedo Gun when on a fixed platform has been settled by actual trials, and is very fully conceded in the report of the board referred to by the general manager. It does not depend upon the firing of a very few shells carrying insignificant charges, nor does it have a record which would render it prudent for the gunners to get within a bomb-proof when it is fired.”

The *Army and Navy Register*, March 24, 1888, states that Mr. Graydon recently filed with the Secretary of War charges against Captain Zalinski of conduct unbecoming an officer and gentleman, in that he is said to have publicly made unjust reflections upon the Graydon dynamite gun. Lieutenant Graydon asked that a court-martial be ordered for the trial of Captain Zalinski on the charges, and that the members of the Army Board of Ordnance be summoned as witnesses. Assistant Secretary Benet declined to entertain the request for a court-martial, on the ground that if Graydon’s business interests have been damaged by statements made by Captain Zalinski, a military tribunal could afford him no relief. From the same journal, March 17, 1888, we learn that the House Military Committee has determined on a favorable report of the bill appropriating \$10,000 for the conduct of experiments with Lieutenant Graydon’s dynamite shells, and recommended that one of the old monitors be placed at his disposal for use as a target for these projectiles.

In discussing Captain Zalinski’s paper on “The Naval Uses of the Pneumatic Torpedo Gun,”* we have said: “In considering the effect of the pneumatic gun projectile, it becomes evident, from the material of which it is made, the lightness of its walls, and the low velocity

* Proc. Nav. Inst. 14, 44; 1888.

with which it is propelled, that penetration is impossible. In fact, Captain Zalinski states that the shell will be crushed on impact; then the conditions which prevail tend to produce a low degree of efficiency. But to meet this criticism Captain Zalinski has devised a most ingenious hypothesis. He holds that the inertia of the explosive will act as a tamping or as a confining envelope. *This hypothesis is one which easily admits of being experimentally tested, and it is much to be regretted if Captain Zalinski has failed to do this.*"

In reply to this Captain Zalinski says :* "Had Professor Munroe carefully read some of the papers previously published on the gun experiments, and portions of which he had republished in the U. S. Naval Institute Proceedings, he would have seen that the value of a tamped charge as compared to an untamped charge had been fully recognized, and that definite experiments had been tried proving this. These experiments were made by explosions of charges suspended against iron plates, and by firing the charges from the pneumatic gun against the iron plates. The Professor misapprehends as to the arrangement of the shell. It is not intended that the part containing the charge is to be crushed on impact before explosion can take place. The electrical arrangements are such as to insure explosion before the body of the shell can be crushed. In this way the tamping effect of the encasing shell is obtained, as well as from the initial detonation taking place at the rear of the charge."

Such résumés and notices as we have made of papers relating to the gun experiments will be found in **11**, 285-293, 767-769; **12**, 616-617, and **13**, 567-573. Lest we have inadvertently done Captain Zalinski an injustice we have again carefully reviewed the sources from which these abstracts were taken, and the only experiments of the kind which we find described are in "The Pneumatic Dynamite Torpedo Gun," published in the *Jour. Mil. Serv. Inst.* **8**, 1-35; 1887. In the reprint which we possess we find on pages 9 and 10: "As soon as a suitable battery had been selected, arrangements were made to try experiments upon iron plates to determine the best details of arrangement of the charge and of fuze. The following experiments were tried:

"An iron target was constructed of plates of the English ship Nankin, sunk in the harbor and being raised by the Engineer Department. The plates were supported against the interior parade wall, and the gun was placed outside of the fort, at the sally-port, 60 yards

* Loc. cit. **14**, 53; 1888.

from the target. A blank shell charged with sand, total weight 30 pounds, was fired. It penetrated three plates, aggregating 2.5 inches. A similar shell, charged with dynamite, having no fuze, intended to explode on impact, penetrated only a single plate, and its effect was actually *less* than the blank shot previously fired. Another shell fired with a detonating fuze in the front of the charge did but little more damage. An electrical fuze was then arranged so that the circuit should be closed when the body of the shell was one-eighth inch from the target. The primer was placed in the rear part of the charge. To further insure against premature explosion by simple impact, a thin layer of cotton waste was placed in front of the shell. The resulting explosion was the most effective produced; the six plates of the target, aggregating 4.5 inches, being broken through and indented in nearly a circular area of about 18 inches diameter. The stone wall in the rear was also somewhat broken by the shock.

“It was evident from the results obtained that the effect to be produced by the explosion of the dynamite shell would not be limited to simple puncturing of a target, but that it would produce cracks and breaks at points distant from the point of impact. This was shown in some experiments upon the stern-post of the Nankin, a forging about 5 inches by 8 inches cross-section. Charges of 3 pounds were exploded upon it. They simply indented the piece at the point of placement, but broke pieces of 2 feet in length at the extremities 6 feet and 8 feet distant, and produced large cracks at other points.”

Again, pages 19 and 20, he says: “An experiment tried by Commander Folger, U. S. Navy, is often quoted. In this a charge of 100 pounds of dynamite was suspended against an iron target consisting of eleven one-inch plates, strongly bolted together, and backed by 20 inches of oak well braced. The result was an indentation of only about 2 inches, extending over an area of two feet. From this the conclusions are published, ‘that a modern armor-clad will not receive material injury by the explosion in superficial contact with iron over-water plating of very large charges of dynamite.’ The superficial contact of the charge, as exploded, did not to my mind represent the conditions at the instant of explosion of a shell from the pneumatic gun. The element of tamping was here entirely lacking. To test this matter in a small way, the following experiment was tried: * A cartridge of 8 ounces of dynamite was suspended in ‘superficial contact’ with an iron plate three quarters of an inch thick, and there

*Vide Proc. Nav. Inst. 13, 570 ; 1887.

exploded. The result was a simple indentation of the plate. A charge of 8 ounces was again suspended against the plate, but over it was loosely suspended a piece of angle iron open at both ends, and of such size that the inscribed circle between its sides and the plate was less than the cross section of the charge, which was cylindrical. Thus there was no direct pressure against the cartridge. Yet a large elliptical hole was blown through the plate considerably longer and broader than the cartridge. This experiment was repeated with almost identical results. When two plates were placed together, a hole was blown through *both* plates."

Among the appendixes to the *Annual Report of the Chief of Ordnance, U. S. A.*, soon to be published, is one prepared by Major George W. McKee, on "The Present Status of Dynamite as an Explosive for Shells." Prefacing it with a brief history of the discovery and use of nitro-glycerine, he says: "Nobel's explosive gelatine or blasting dynamite has been used in this country by United States officers, to the entire demonstration of the fact that this high explosive, contained in a shell as a bursting charge, might be fired from a gun. The ordinary blasting dynamite made by the company (some of it experimentally modified by about three per cent of camphor) was used, and enough shells were thrown from the bores of the old mutilated guns used in the experiment to demonstrate the fact that the dynamite could be projected in shells from an 8-inch rifle gun with a 40-pound charge of powder. The great chemist, Nobel, never, perhaps, thought of applying his invention to this delicate test; but his powerful and wonderful gelatine, made only to be detonated in mines and the like, stood in several instances the tremendous initial shock of the gunpowder, and, by the aid of the rectangular diaphragms devised by Captain Whipple, of the Ordnance Department, stood, what is thought to be equally dangerous, the heat developed by the angular velocity. If the gelatine had been especially undertaken by these chemists for a military and not an industrial agent, and enough time and means had been at hand to perfect the diaphragm, it is believed all of the shells would then have become, as they will be in future, high-explosive batteries, projected with as much safety as though they had been charged with black gunpowder."

Major McKee, in reviewing various experiments that have been conducted under the direction of the Ordnance Department, speaks

of them as follows. Of the method exhibited by Mr. Snyder* he says: "He did fairly well with some of his firing at the Hook and on the Potomac, near Washington, D. C., and, as he is a man of inventive talent and an American, no one wishes him more success in his future experiments with dynamite than the men who were delegated by the Government to supervise and report upon those he originally undertook." In the experiments with shells loaded with dynamite, conducted by Brevet Brigadier-General John C. Kelton, at Point Lobos, near San Francisco, Cal., in March, 1885, no specially camphorated or otherwise prepared explosive was used, but the shells were charged with the crude blasting industrial dynamite. Three rounds were fired from a 3-inch wrought-iron rifled gun, shells with 200 grams of dynamite, and a variable charge of projection. The target was a large rock at 157 yards distance. In the first two rounds the shell burst into innumerable pieces on striking the rock, but in the third it burst within the piece. Colonel Kelton considered this experiment as very satisfactory, since it demonstrated the possibility of employing dynamite in shells, as well as the great strength of this great explosive; and he estimates that for the effective use of the artifices, which, according to him, is to destroy ships, one half the length of the projectile is the penetration needed, requiring 0.001 of a second, and he expects it will be successful.

After describing some experiments at Sandy Hook in 1883, Major McKee sums up the results as follows:

"As detailed in the records, three shells were fired with fulminate of mercury fuzes. The fulminate was too sensitive to stand the shock, and it was found afterwards that the gelatine needed no detonator.

"Although the tests made were very few, it would nevertheless appear from them—

"1. That the shells explode after clearing the muzzle, and therefore the detonation of the gelatine is due to some cause other than the shock of discharge—very possibly the heat generated by angular velocity.

"2. This is corroborated by the fact that one shell passed through a 2-inch board target without explosion.

"3. The gelatine used in these tests not being camphorated renders it highly probable that a certain percentage of camphor added would

* Proc. Nav. Inst. 12, 617; 1886, and 13, 411; 1887.

establish a compound which could be fired successfully in a specially constructed shell.

“ 4. The gelatine does not require a fuze or detonator of any kind.

“ 5. It is believed the shell which destroyed the 3.2-inch breech-loading gun broke from the shock of discharge, or admission of powder gas, and thus detonated the gelatine.”

In the summer of 1884 the Ordnance Board fired four cast-iron screw shells from an 8-inch muzzle-loading rifle, using 40 pounds of powder in the gun, and from 5 to 8 pounds of gelatine in the shells at each discharge. The gun was mounted on a cradle and directed at a target 383 feet distant. One of the shells burst at or near the muzzle with little comparative violence. The other three reached the target, penetrated about seven inches, and detonated from the shock. These trials led to the making of six steel shells, three of them being cast and three forged. Analysis of the facts connected with these experiments shows—

“ 1. That the 3-inch shells designed for gunpowder charge, when loaded with Hill's explosive gelatine three months old, all cleared the gun without injuring it in the slightest.

“ 2. That the shells, having to be charged through the fuze holes with the dynamite, were necessarily packed loosely, thus subjecting the charge to the powerful action of angular velocity.

“ 3. That in the trials made with the 3.2-inch, two Butler shells charged with black gunpowder broke up ‘at or near the muzzle’; while of the two Butler shells charged with Nobel's gelatine, or dynamite, one broke up ‘at or near the muzzle,’ and the other reached the target and exploded on impact.

“ 4. That in the trials made with the same 3.2-inch gun, using thin Hotchkiss shrapnel cases, charged with Nobel's dynamite, or gelatine, all cleared the gun in safety (one reaching the target after passing through two-inch boards) with the exception of one, which the Board reported on as follows: ‘It either broke from the shock of discharge or admitted powder gas.’

“ 5. That all the trials with the 8-inch shells charged with fresh Nobel's dynamite, or gelatine, were successful, three of the shells detonating at the target, and one only exploding at or near the muzzle; that the gelatine used when the premature explosion took place was sixteen months on hand in this country after crossing the ocean, and therefore not such as was recommended by General Abbot, or contemplated by the Board.”

Major McKee's conclusions are as follows : that the United States officers undertaking the investigation of this subject were necessarily compelled to institute their inquiries *de novo*. All foreign information was so meagre, so unsatisfactory, and so shrouded in mystery, in accordance, doubtless, with the policy of the European governments, that it was seen, after careful investigation, that all trustworthy knowledge would have to be gleaned by Americans through experience. In obtaining this experience, devices have been experimented with, invented by Mr. Snyder, who presented several plans; Mr. C. P. Winslow, with a nitro-glycerine shell, in which the glycerine and combined nitric and sulphuric acids are placed in separate glass vessels within the shells; Mr. Garrick, with a mortar and projectile for nitro-glycerine; Mr. D. P. Hill, with an 8-inch explosive gelatine shell; Mr. Stevens, with a double shell for high explosives; Mr. Graydon, with a shell containing the dynamite in capsules; Mr. Taylor, who brought his own gun and attempted to use dynamite as a propulsive charge; and Mr. Smolianoff, experiments with whose gun were made as late as last October.

In all these trials, Major McKee said, as to the practicability of using dynamite as a shell explosive, that it was well understood by the officers undertaking them that the crude blasting compound of industry, which was the only available explosive attainable, was not the eventual product of chemistry which would satisfactorily answer this purpose. It was known that great improvements had been made in the dynamites of all kinds, especially in the blasting dynamite or gelatine of Nobel, and that these compounds presented in transportation by all modern conveyances, and in all mining and other industrial works, as much, if not greater, safety than the black war, sporting, and the blasting gunpowders of commerce. With this status of dynamite apparent, it was seen that the time had arrived for military men in the United States to begin with it as a shell explosive, with some possibility of success. When it was demonstrated that the freshly prepared crude commercial dynamite might be fired in a shell from an 8-inch gun with a charge of forty pounds of black gunpowder, the only question that then remained was as to the stability and reliability of the compound through age. And when, after sixteen months' storage, it appeared to be more sensitive to shock, the Ordnance Board recommended that no more experiments be made with it until it was further camphorated, or otherwise treated by competent chemists. And it was ascertained further, in these few and inexpen-

sive tests, that the heat developed by the angular velocity was a more potent factor in detonating the dynamite than was the shock of discharge. It has been seen, also, that, since the comparatively recent discovery of nitro-glycerine, its development has been rapid in the protean forms of dynamite. In Europe experiments are being constantly conducted to perfect this agent, and doubtless they will succeed. Even now they claim in France and Germany to have perfected melinite and helphonite (?), compounds probably of nitro-glycerine and some of the ethers (sic). In Russia they also announce some new improvements that are not known here. But in the near future there is every probability that the problem will be solved in this country.—*Science* **II**, 153, 154; March 30, 1888.

The surgeons who examined the bodies of the soldiers killed by the explosion of melinite at Belfort,* report to the French Chirurgical Society that of the seventeen men hit only six lived. The bodies of the slain, it is said, were literally torn into shreds, and it is the belief of Dr. Tachard and his assistants that much of the substance exploded only after entering the bodies, or, in other words, that melinite as now compounded explodes at different periods, some early, some late; the first bursting the shell into fragments, and the latter adhering to these fragments, exploding when driven home. They remarked on the absence of burns and of poisoning. The bodies of the wounded were found to be tattooed as if with explosive dust.—*Army and Navy Jour.* **25**, 621; Feb. 25, 1888.

On November 3, 1887, Dr. S. H. Emmens made some public experiments at his home on Prospect Avenue and One Hundred and Sixty-fifth Street, N. Y., to demonstrate the qualities of his new explosive, "Emmensite." "The explosive is composed of two cheap and easily obtained materials; one is an extract from coal, and the other a mineral substance. The mixture may be pounded in a mortar, and neither ingredient separately shows any trace of an explosive nature. Another valuable quality which is claimed for emmensite is that it may be melted and fused into any shape, as a solid block, or may be granulated in various sizes; consequently, it may be used either as a high or low explosive. According to Dr. Emmens' computation, it can exert a pressure of 283 tons to the square inch, the next highest pressure being exerted by pure nitro-glycerine, 264 tons. The speed

* *Proc. Nav. Inst.* **13**, 581; 1887.

of explosion is greater than that of any other practicable explosive, except fulminate of mercury. When used in a compact form, its highest possibilities of speed are obtained, and it is then suitable as a blasting agent. When manufactured in the form of powder, the rapidity of explosion is lessened in proportion to the coarseness of the grains, and it may then be employed in firearms. To-day a 32 caliber Smith & Wesson was fired from a distance of 6 feet at an iron plate $\frac{1}{16}$ of an inch thick. With four grains of emmensite the ball nearly pierced the plate, while with ten grains of powder the ball made only an indentation. A leaden hemisphere was placed on a rock; upon this were placed, successively, one ounce cartridges of gunpowder, explosive gelatine, dynamite, and emmensite. While the other explosives bent the lead, it was shattered by the emmensite. An iron plate 6 inches square was then suspended from the branch of a tree. A one-ounce dynamite cartridge placed on the plate simply bent it; a cartridge of explosive gelatine almost broke it; while the same amount of emmensite made a hole through the plate as large as a man's fist. Then, to show that the explosive would strike upward as well as downward, a cartridge was suspended and a leaden hemisphere was placed over it. After the explosion the lead was found to be not only shattered on the under side, but on its upper side also. The explanation is that the explosion took place with such rapidity as to force the gases through the pores of the lead, a thing which happens when the outer plates of a piece of artillery are injured and the inner plates remain unaffected by the shock. A piece of emmensite was immersed in a barrel of water for $1\frac{1}{2}$ minutes and then exploded easily. Experiments were also given showing the value of the invention for pyrotechnical purposes. In its ordinary state, emmensite is a yellow powder and is a powerful dye, and the hair and beard of those handling it have become of a brilliant blood red."—*Boston Herald*, Nov. 4, 1887.

At the session of the French Academy of Sciences for December 12, 1887, Professor Berthelot presented a paper on the "Different Modes of Explosive Decomposition of Picric Acid and the Nitro-Compounds." After noticing the general belief which has existed regarding the explosiveness of picric acid, and alluding to Colonel Majendie's report* on the recent accidental explosion in England, he described the following experiments. When a notable quantity of

* Proc. Nav. Inst. 14, 149; 1888.

picric acid is heated in an open flask or capsule, it first melts and then volatilizes, giving out fumes which burn with a smoky flame, but no explosion takes place. When, however, a test tube about 25 to 30 millimeters in diameter is heated over a gas jet so as to produce a visible red, but without melting the glass or deforming the tube, on dropping into it some few milligrams of the acid, in crystals, a sharp detonation occurs, attended with a bright white light and the characteristic noise. When the experiment is performed in nitrogen gas, a few flakes of carbon are deposited; in ordinary air the result is the same, but no carbon is left. On increasing the quantity of picric acid, without, however, exceeding a few centigrams, the addition may cool the bottom of the tube sufficiently to prevent immediate detonation, but the substance is at once volatilized, and an explosion, attended with flame occupying a great part of the tube, occurs. This explosion is not so sharp as the more local detonation, and more carbon is apparently deposited. An explosion of this nature may be produced with a few milligrams of material, by using a glass tube coated with the carbon of a previous explosion. With a decigram of the acid and a fresh tube, the reaction will be slower still, yet a series of deflagrations with red flame will be observed, while the vapor will catch fire at the mouth of the tube. Finally, with large quantities the acid is decomposed, there being abundant fumes and partial volatilization without deflagration. Other nitrogenized bodies, less rich in oxygen than picric acid, such as the mono- and dinitro-benzenes and the nitro-naphthalenes, were experimented with and afforded similar results, thus leading to the conclusion that the mode of decomposition of all these nitro-substitution compounds depends on the initial temperature of decomposition.

Respecting picric acid more especially, M. Berthelot's conclusions are as follows: Should a nitro-compound, such as picric acid, while burning in large masses, happen to heat the sides of the containing enclosure to a degree sufficient to induce incipient deflagration, the deflagration might contribute to further increase the temperature of the enclosure, and the phenomenon might occasionally be transformed into a detonation. It would even suffice that the detonation should occur in an isolated point, either during a fire or owing to the local overheating of a boiler or apparatus, to enable it to originate the explosive wave and propagate itself by influence throughout the whole mass, causing a general explosion.—*Comptes Rendus* **105**, 1159–1162; Dec. 12, 1887.

Picric acid, picrates, and mixtures of picric acid with certain other substances, being "under certain conditions specially dangerous to life and property by reason of their explosive properties," an Order in Council has been issued in Great Britain under the provisions of the Explosives Act, 1875, declaring :

"(1) Picric acid when in process of manufacture or storage shall (for whatever purpose used or manufactured) be deemed to be an explosive within the meaning of the said Act for all the purposes of the said Act, subject to the exceptions following: (a) Picric acid when wholly in solution shall be exempt from being deemed to be an explosive within the said Act; and (b) picric acid which does not fall within the exemption above set forth, but which is being manufactured or stored in a factory, building, or place exclusively appropriated to the manufacture or storage of picric acid, and in such manner as effectually to prevent any picric acid from coming into contact (whether under the action of fire or otherwise) with any basic metallic oxide or oxidizing agent, or other substance capable of forming with picric acid an explosive mixture or explosive compound, or with any detonator or other article capable of exploding picric acid, or with any fire or light capable of igniting picric acid, shall be exempt from being deemed to be an explosive within the said Act. (2) Picrates and mixtures of picric acid with any basic metallic oxide, or any oxidizing agent, or with any other substance capable of forming with picric acid an explosive mixture, or any explosive compound (for whatever purpose used or manufactured), shall be deemed to be an explosive within the meaning of the said Act for all the purposes of the said Act, unless such picrates or mixtures be wholly in solution." —*Jour. Soc. Chem. Ind.* 7, 48; Jan. 31, 1888.

Fleck states in the *Chem. Centr.* p. 99, 1887, that if a solution of picric acid is evaporated in a porcelain dish, the residue then being moistened with a 10 per cent solution of hydrochloric acid, a small piece of pure zinc being added to this and the whole allowed to remain in the cold for some hours, a fine blue color is developed. A solution of dinitrocresol (Victoria Yellow) treated in the same way yields a bright blood-red color. The original solutions are best made by extracting with alcohol.—*Jour. of Anal. Chem.* 2, 120; 1888.

In a lecture delivered before the Aldershot Military Society, February 2, 1888, by Sir Henry Halford, on the new magazine gun

recommended for adoption by the British service, he says of the explosive to be used: "We take Curtis and Harvey No. 6 for instance, but that requires a great deal of room, and the Swiss have managed to compress their powder in such a way that they can put 70 grains into the space occupied by 55 of our powder. It is quite true that powders for small arms are in their infancy. We hear of nitrate powder, smokeless powder which will be suitable and accurate for rifles. So far I believe it has not been used with success. The French find it will not keep. For use it is impossible to take a powder that will not keep for at least ten years. If we adopt a powder without adequate time being taken to test its storage capabilities, it will be a bad thing for the country. But we can take Rubini powder and work with that, and meanwhile make experiments with these nitrate powders and see if anything can be done towards getting a smokeless powder for the future."—*Army and Navy Jour.* 25, 601; Feb. 25, 1888.

Prof. W. Mattieu Williams infers, from an examination of Count Rumford's "Essay on Gunpowder," that he produced solid carbonic acid* in the course of his experiments on the explosive force of that composition. In an experiment with a confined cylinder the Count observed "an extremely white powder, resembling very light white ashes, but which almost instantaneously changed to the most perfect black color upon being exposed to the air." Prof. Williams supposes that this white evanescent ash-like deposit was solid carbonic acid. The change to black mentioned by Rumford was caused by the instantaneous evaporation of the acid which revealed the ordinary black deposit of gunpowder beneath it. The pressure under which the experiment was conducted was 9431 atmospheres, which is abundantly sufficient to effect the solidification of carbonic acid.—*Pop. Sci. Month.* 29, 718; 1886.

The Royal Prussian Fire-Damp Commission has carried out a series of experiments in the Royal coal-mine near Neunkirchen, the results of which go far to confirm Mr. W. Galloway's † theory of the agency of coal-dust alone, and in conjunction with fire-damp, in propagating explosions in mines. At the mine in question is a blower for fire-damp at a depth of 131 yards below the surface, which gives off 0.9 cubic feet of gas per minute. For the experiments cannon were planted at the closed end of a horizontal gallery 167 feet long, having

* *Proc. Nav. Inst.* 12, 621–623; 1886.

† *Ibid.* 12, 429; 1886.

a branch 33 feet long, starting at a distance of 93 feet from its closed end. The branch gallery was closed at both ends with two-inch planking. One gun was fired when the gallery was free from fire-damp and from coal-dust; the flame of the shot was a little over 13 feet long. In a second experiment the floor of the gallery was strewed with coal-dust 1.17 inches thick for a length of 65 feet. The shot gave rise to a loud detonation, and the resulting flame filled the gallery to a distance of $88\frac{1}{2}$ feet. The inner planking of the branch gallery was broken. In the third experiment the gallery floor was strewed with coal-dust for a length of 130 feet. The flame traversed the whole length of the gallery with great velocity, and came out at the open end to a distance of 16 feet, or 183 feet in all. It also emerged from the branch gallery to a distance of several yards. The outer partition of this gallery was broken into small fragments. For the fourth experiment, the partitions in the branch gallery were replaced, coal-dust was strewed on the floor for a distance of 65 feet, and a volume of $35\frac{1}{4}$ cubic feet of fire-damp was introduced and completely diffused. The firing of the shot produced a flame 190 feet long, accompanied by a report like a thunder-clap. The inner brattice of the branch gallery was broken and drawn several yards into the main gallery, but the outer one remained intact. The incidental effects of the last two shots also indicated how tremendous a force had been let loose when coal-dust formed one of the elements of the explosion. These experiments were typical of two hundred similar ones that had been made with from one to seven guns, all marked by results sustaining the coal-dust theory.—*Pop. Sci. Month.* **27**, 714; 1885.

We are indebted to Sir Frederick Abel for a copy of his very valuable paper on "Accidents in Mines," which is reprinted, together with the discussion, as a pamphlet of some 200 pages, from the *Proc. Inst. Civ. Eng.* for 1886-1888, and from which we propose to abstract for a later number of these Notes.

A striking new experiment, exhibiting the explosive nature of "Nitrogen Chloride," is described by Prof. Victor Meyer in the *Ber. Chem. Gesell.* **21**, 26-28; 1888. A few drops of yellow chloride were prepared in the usual manner by inverting an exceptionally thin flask filled with chlorine gas in a leaden dish containing a solution of ammonium chloride. Instead, however, of gently agitating the apparatus so as to cause the drops to fall into a smaller leaden capsule placed beneath the mouth of the flask, they were allowed to float freely

upon the surface. The whole apparatus was then enclosed in a cover-box fitted with stout plate-glass sides, through the top of which was passed a bent pipette, turning up below just under the mouth of the flask, and connected outside with a dropping funnel containing ammonium chloride solution and a few drops of turpentine. When sufficient nitrogen chloride had collected, the tap of the funnel was carefully turned so as to allow a little turpentine to slowly rise in the flask. After a moment or two it reached the surface and mingled with the nitrogen chloride, causing a brilliant flash of light and a loud explosion, which Prof. Meyer likens to a thunder-clap, so much more powerful is the detonation in a confined space. The flask, of course, was shattered, not into powder, but into tolerably large fragments; the plate-glass box, however, even after many repetitions of the experiment, remained intact, a small door on the side away from the observers having been left ajar so as to prevent any notable increase of pressure. Curiously, the nitrogen chloride never entirely exploded; a part remained in the distorted leaden dish and maintained an incessant fusilade for more than a minute.

At the last meeting of the Göttingen Chemical Society, Dr. Gattermann read a preliminary note upon his recent researches on "Nitrogen Chloride." From his analyses it appears pretty clear that the yellow liquid is a mixture of at least two distinct chlorides, which he has hopes of being able to separate. During the course of his experiments the reason of its capricious behavior, which has been the cause of so many painful accidents in the past, was happily discovered. It is decomposed by the actinic rays of light, being rapidly acted upon by sunlight with periodic spontaneous explosions, and being at once fired by exposure to the rays of burning magnesium. Hence the further study of this subject must be carried on in the dark room.—*Nature* 37, 350; Feb. 9, 1888.

These results of Gattermann's with nitrogen chloride recall those obtained by Guyard with nitrogen iodide, *Bull. Soc. Chim.* 41, [2] 12; Jan. 1884. He found the action of light on this amide so marked that he proposed to use the phenomenon for photometric purposes.

Through the courtesy of Dr. Wolcott Gibbs we learn that in 1843 or 1844, while Dr. John Torrey was exhibiting to his class at the College of Physicians and Surgeons of New York the oxidizing effect of fuming nitric acid on phosphorus, a tremendous explosion ensued. The experiment was made by placing the fuming nitric acid in a

stout platinum crucible which rested on a stone slab, and dropping in the piece of ordinary phosphorus from the end of a rod which held it. The explosion followed immediately on the phosphorus coming in contact with the acid. A curious result of the explosion was, that while the sides of the platinum crucible were extended, the bottom was driven upward, so that the vertical cross-section was changed from the shape of a U to nearly that of a W.

In discussing the "Origin and Structure of Meteorites," *Pop. Sci. Month.* 29, 374-386; 1886, M. A. Daubrée says nothing in the exterior form of meteorites is more striking than a general aspect indicating that they are parts of a broken body. When we compare hundreds or thousands of stones of the same fall, we find that they all present polyhedral forms, like those of stones broken for a macadamized road, except that the angles are more or less rounded. Even meteoric iron exhibits this angular shape, showing that its malleability and extreme tenacity have not preserved it from a violent rupture. It seemed impossible that such effects could be produced solely by the action of the air, especially in the upper regions where it is in an extremely rarefied condition. But light has been thrown upon the problem since the introduction of the new explosives, which illustrate, in their industrial applications, the prodigious force that gases are capable of exerting, even in small quantity, when they are suddenly animated by a considerable tension. The explosion of a kilogram of dynamite will break up bars of steel which a pressure of a million kilograms would hardly crack. Similar conditions exist in the upper strata of the atmosphere, slight as their density may be, when a meteor moving with planetary velocity strikes upon them. The body compresses the air more rapidly than it can yield, and transmits an equivalent motion to its own molecules. Under these circumstances, in the successive detonations caused by an enforced rotation, iron and the most tenacious bodies will fly into pieces as if they were struck with a pile-driver.

There is another no less characteristic feature of the surface of meteorites which testifies to the violence of the mechanical action produced upon them by the atmospheric rebound, exhibited by rounded cavities resembling finger-marks. They appear in the stony meteors, but are particularly characteristic of the iron masses. These marks were at one time attributed to transient explosions taking place during the course of the meteor through the air; but experiment has shown that the same appearance is produced in

bodies which are acted upon by an explosion of dynamite, in the grains of coarse powder that drop, half consumed, from the mouth of a cannon when it is fired, and upon the touch-hole of the cannon. They are all due to the same cause—to the erosive action of gas revolving rapidly and moving spirally and under high pressure against the projectiles, boring into them as if it were a gimlet. The mechanical action is accompanied and aided by a chemical action which is dependent upon the combustible nature of iron at high temperatures. Although these blister-holes are worked only on the face which is exposed to the direct pressure of the gas, meteorites present them on various sides, and sometimes over their whole surface. This arises from the rotatory character of the motion of the body, which makes it present every side in succession to the front.—(*From Revue des Deux Mondes.*)

Dr. H. G. Piffard proposes the use of a mixture of gun-cotton and powdered magnesium for the production of a light by which instantaneous photographs may be made at night. The burning magnesium furnishes a light which is rich in actinic rays, and the burning gun-cotton supplies the heat necessary to cause the instantaneous combustion of the magnesium. The mixture has been flashed from a pistol.—*Newport News*, Oct. 31, 1887.

According to the *Sci. Am. Sup.* 25, 10230 ; April 7, 1888, a new use for soluble gun-cotton has been found in the manufacture of a fibre called "Artificial Silk." This fibre is prepared by De Char-donne by dissolving 3 grams nitro-cellulose in 100 to 150 cc. of a mixture of equal parts of alcohol and ether. 2.5 cc. of a filtered 10 per cent solution of ferrous chloride in alcohol, or of stannous chloride, and 1.5 cc. of a solution of tannic acid in alcohol are then added. The filtered liquid is placed in a vertical reservoir having at its bottom a blow-pipe nozzle of glass or platinum. This pipe forms an acute cone with an orifice of from 0.10 to 0.20 mm., the thickness of the margin not exceeding 0.1 mm., and opening into a vessel of water acidulated with one-half per cent. of monohydrated nitric acid. The level in the reservoir being some centimeters higher than in the vessel of water, the overflow proceeds easily. The fluid hardens at once in the acidulated water, and may be drawn out by a uniform movement in the form of a thread which must be dried rapidly by traversing a current of dry (not hot) air, and may be wound up as

soon as dry. Soluble coloring matters may be introduced into the solution so as to obtain threads of all colors.

The *Journal du Matelot* of Jan. 14, 1888, contains an account of an invention of M. W. Meissel's, of the North German Lloyd line, for throwing oil from a ship upon the billows which endanger her safety. This consists in attaching thin zinc cylinders, filled with oil, to the end of a rocket, so arranged that the explosion of the rocket shall rupture the cylinder and distribute the oil. Experiments were made from the *Vesra* in the middle Atlantic and they gave excellent results, and proved that they could be fired directly ahead either in the air or under water.

The *San Jose (Cal.) Mercury* of January 22, 1888, cites the results of several experiments with this rocket. In one experiment the rocket was thrown to a distance of 1000 feet. By the explosion of five rockets at from 1200 to 1500 feet from the ship, a space of from 1500 to 2000 square feet of water was covered with oil and the waves were at once smoothed. The rocket was fired 900 feet against a gale. The value of the invention to deep-water sailors consists in the certainty of explosion of the rocket at sufficient distance to leave the vessel in calm water during a gale.

The *Newport News* of April 2, 1888, states that a patent has been granted Mr. Timothy Akin, Sen., of Gosnold, one of our branch pilots, for a rocket or projectile made of metal and filled with oil, which is to be thrown from the shore near or around vessels that are stranded. It can be thrown from the same gun that throws the life line across stranded vessels. The rocket sinks in the ocean and the oil that is contained therein escapes and floats on the surface, which makes the water comparatively smooth and stops the sea from breaking, thus enabling the life-saving crews to work in smooth water while they are engaged in their perilous duty going to and fro from the stranded vessel saving life. Capt. Akin has tried them and they work well. He intends to send them to the different life-saving stations so that they can be fairly tested and tried.

Mr. Wolcott C. Foster gives in the *Engineering News* 19, 254; March 31, 1888, a "List of Explosives Containing Nitro-glycerine," in which the names of some forty different explosives, together with the different grades of each and their nitro-glycerine contents, are enumerated.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH,
OCTOBER, 1888.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XVIII.

In November last, at Sandy Hook, in the presence of the Army Ordnance Board, three rounds were fired with shell charged with insensitive nitro-glycerine, according to the method of S. D. Smolianinoff, described in these Notes.† The firing was from a 100-pounder Parrott. The weight of empty shell in the first two rounds was 89 pounds, and the weight of explosive was 4.6 pounds; in the last round the shell weighed 82 pounds, explosive 4.1 pounds. Except that the turret section had no roof, the target was in all respects similar to that used in the Graydon‡ experiments, even in the respect that it had been fired at before and showed the indentations of former shots. It was mounted in the same manner, and the range also was the same, 101 yards. The powder charge decided on was eighteen pounds Dupont powder. Previous trials had shown that this charge with an 87-pound projectile gave a velocity of 1494 foot-seconds and a pressure of 26,700 pounds per square inch.

First round.—Shell (not fuzed) struck the target in the left-hand lower corner, twelve inches below the horizontal joint and within the edge of an old indentation, and broke into minute fragments. A low

*As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. *Address Torpedo Station, Newport, R. I.*

†Proc. Nav. Inst. 13, 173; 1887.

‡Proc. Nav. Inst. 14, 156; 1888.

order of explosion resulted, as evidenced by the black smoke and the character of the sound. The front plate was cracked to the joint, otherwise the damage was all on the surface. Several bolts that had been broken in previous firings were jarred out by the shock.

Second round.—Shell fitted with percussion detonating fuze. Struck slightly above and six inches to the left of the first shot, and broke up. Explosion, although not of the first, was much higher, order than in the previous round. A $2\frac{3}{8}$ -inch bolt was broken in two, and some slight surface damage was done. The wooden foundation of the turret was badly broken up.

Third round.—Shell (fuzed) struck a few inches above No. 2 shot and broke up. Explosion of lower order than in No. 2 round, and higher than in No. 1. No material damage done to the target.

The weakness of the cast-iron shell used in these rounds, and also the shape of the head, which was adapted to a nose-fuze, precluded any possibility of penetration, without which no really useful result could be looked for. The firing was successful in the respect that no damage was done to the gun.—*Gen. Information Series* (U. S. Navy), 7, 378; 1888.

Mr. Hiram Maxim, the inventor of the automatic machine and R. F. guns, has recently secured letters patent on designs for a dynamite gun, for which several advantages are claimed over the Mefford* gun.

In the preamble to his specifications Mr. Maxim says: "It has heretofore been customary to utilize compressed air in dynamite guns for discharging the projectile therefrom; and in order to obtain a higher muzzle velocity of the projectile it has been necessary to make such guns with very long barrels, and to employ air under very high pressure. By my invention I am enabled to reduce greatly the length of the barrel and the pressure of air employed, and, at the same time, to obtain a very high muzzle velocity."

Instead, therefore, of charging the gun with compressed air alone, Mr. Maxim uses a mixture of air and some volatile hydrocarbon (gasoline, for example), in such proportions that there will be just sufficient oxygen in the air to convert the hydrogen of the hydrocarbon into water, and the carbon into carbon dioxide. This mixture may be used at a pressure equal to about one half of that ordinarily

* Proc. Nav. Inst. 13, 567; 1887.

employed in pneumatic dynamite guns. After the projectile has been driven by the expansive force of the compressed gas that enters at the initial pressure, through from one quarter to one half the length of the bore, the mixture is caused to explode, and the pressure is at once increased about eightfold.

The apparatus for causing this explosion consists of a detonating cartridge, so placed in an axial chamber in the wall of the gun as to have a longitudinal play of about a quarter of an inch; the chamber being some distance in advance of the projectile when seated, and the outer end of the chamber being fitted with a steel firing pin. The compressed air and hydrocarbon having been introduced into the bore, the projectile moves forward until it uncovers the interior opening of the axial wall chamber, when the gas, impinging upon the detonating cartridge, drives the primer against the firing pin and ignites the mixture in the bore.

Two projectiles have been designed, one for rifle, the other for smoothbore guns. In the latter case the rotary motion is imparted by means of vanes or screw-blades, as with the projectile for the Mefford gun; while the bursting charge of the shell is detonated by means of a capsule and firing pin in the hollow tube to which the blades are attached. It is not understood that any gun of this description has yet been built.—(*Loc. cit.* 352.)

The Rival Air-Gun Company have issued a large quarto pamphlet* with seven plates, entitled "The New Pneumatic Gun or Aerial Torpedo Thrower," describing a device for firing shell charged with high explosives, based upon the inventions of J. W. Graydon. This gun is in principle similar to Mefford's gun, but where the latter is from seventy to fifty-five feet in length, the former is from one half to one third as long. The reduction in length is accomplished by using a greatly increased air pressure, and the company claim to be able to do this with safety, owing to the manner in which the high explosives are packed in the projectile. Owing to this shortening of their length, these guns may be elevated, depressed and trained like any piece of ordnance, a performance which is impossible with the Mefford gun. The guns of this pattern are from three to twenty-one inches in caliber, throwing from six pounds to 1200 pounds of high explosives, under air pressures running up to 3000 pounds per square inch. The range varies with the pressure up to three miles. Besides the short-

* Washington, 1888.

ening of the gun, the great increase in pressure enables them to get a flatter trajectory and greater range than the Mefford gun yields. Other new devices offered in connection with the gun are an air valve, a new condensed fuel for use with the air compressor, and a new fuze. The firing connection for this fuze is operated by the pressure of water, and is regulated for any depth. When that depth is reached, the firing plunger is unlocked and the torpedo is exploded, while, until that condition is fulfilled, explosion from any cause is claimed to be impossible.

It is obvious from these abstracts that this invention is offered in competition with the pneumatic dynamite gun.

Graydonite is a name given to an explosive by J. W. Graydon, for which he claims absolute freedom from danger in handling or transportation, simplicity of manipulation, and a destructive power 400 to 700 *per cent higher than dynamite No. 1*. A circular advertisement contains very favorable reports of a trial of the explosive made at Table Rock quarry on the Potomac, in May, 1887.—(*Loc. cit.* 374.)

Through the courtesy of General H. L. Abbot we have received a copy of the *Forum** for September, 1888, containing a very thoughtful and interesting article by him, on "The Use of High Explosives in War," in which he reviews the progress which has been made in the applications of high explosives to the art of war, and shows that they have proved a most important gain for the engineer in the destruction of material, removal of obstructions in mining and in countermining; that the success thus far attained in firing shell charged with high explosives from gunpowder guns has demonstrated the weakness of our hitherto impregnable fortifications; and that the gain, as between ships and forts, is rather to the advantage of the latter, and is in favor of the rich and powerful nations rather than the poor and weak.

In concluding he remarks: "No reference need be made to the proposed mode of projecting charges of high explosives from pneumatic guns, because no official trials have yet been made with the pattern proposed by the inventors for service; because the ranges claimed are too short to meet the requirements of the problem; and because throwing the new agents from ordinary guns will do away

* 6, 65-73; 1888.

with the supposed need of the invention. That larger charges may perhaps be thrown from a pneumatic tube than from a gun is not very important, because the destructive effect of the explosion increases only with the square root of the weight, *i. e.*, a 400-pound charge is only twice as destructive as a 100-pound charge, and in most cases four 100-pound charges are more to be dreaded than one 400-pound charge."

The *Army and Navy Jour.* 25, 826, May 5, 1888, states that during the progress of some artillery experiments at Fort Tiburina, just outside of Rome, on May 1, a dynamite shell exploded and the Crown Prince of Italy was slightly wounded in both sides. The general commanding the home division of the army was also slightly wounded, two colonels received serious injuries, and two captains dangerous ones.

*Mélinite** is generally believed to be a mixture of fused picric acid, in granules, with trinitrocellulose dissolved in ether. M. Turpin, its inventor, is now free to offer his secret to any government that may choose to purchase it, but the French claim that their *mélinite* of to-day is so different from the original substance that not even the inventor would recognize it, and that they have reached such a state of proficiency in its use as to put them at least three years in advance of any possible rivalry. It is reported that the secret has been purchased by Sir William Armstrong. It is known that experiments with one form of *mélinite* are now progressing in England, but so far the particulars have been carefully guarded.

Precautions are taken to guard not only the secret of the manufacturing processes, but also the performances of the explosive. Notwithstanding this, it has transpired that in the Belliqueuse experiments, the effect of the shell striking against the armored portion of the ship was practically *nil*, the points of impact being marked by only slight surface indentations. On the other hand, the shell that struck the unprotected parts are said to have created "terrible havoc." This expression, which is copied from various editorials of the French press, is a rather vague one, but, at all events, the havoc was such as to cause many French naval experts to advocate a reversion to complete armor; and it is said that the designs of several ships now building (the *Brennus* and *Dupuy de Lôme* are mentioned by name)

* Proc. Nav. Inst. 14, 151; 1888.

have since been modified especially to meet the fire of high explosive projectiles.

It is stated that the French have succeeded in firing *mêlinite* shell from high-power guns with velocities as high as 2000 foot-seconds. The weight of the *mêlinite* charge in this case is not mentioned, but it is known that charges of nearly 70 pounds have been repeatedly fired from the 22-centimeter mortar, with velocities of over 1300 foot-seconds.

Max Dumas-Guilin, in the manual noticed elsewhere, states the explosive force of *mêlinite* to be only three times that of gunpowder; other statements represent it as from five to eleven times as powerful, but M. Guilin evidently has the weight of authority on his side, and is entitled to the greater credence.—(*Loc. cit.* 373.)

The current press reports that an explosion has occurred in a *mêlinite* factory at St. Omer, France, and that before the flames were subdued, six factories and two houses were destroyed.

The Emmens Chemical and Explosives Company, of Harrison, N. Y., have issued a "Report on Emmensite," by Baron Louis H. de L'Espee, in which it is stated that emmensite* is prepared by fusing together five parts by weight of emmens acid and five parts of a nitrate (preferably sodium or ammonium nitrate) in a paraffin bath, and then incorporating six parts of picric acid. Emmens acid is obtained by dissolving commercial picric acid, at a gentle heat, in fuming nitric acid (50° to 52° Baumé), and evaporating, when the new acid is deposited in rhomboidal prisms of a fine yellow color. According to Dr. H. Wurtz, of New York, this acid has the formula of $\text{H}_2\text{C.C}_{12}\text{H}_6(\text{NO}_2)_6\text{O}_2.\text{H}_2\text{O}$, and may be regarded as being intermediate between tri-nitro-phenol and tri-nitro-cresol. Emmens acid differs from picric acid in its crystalline form; in being less soluble in water and alcohol; in giving ruddy vapors when heated, and in possessing a *golden* yellow color. It is claimed that by the process of manufacture of emmensite above described, the whole mass is converted into a compound of emmens acid.

Elaborate calculations are employed to determine the explosive value of emmensite as compared with nitroglycerine and other high explosives, and taking dynamite No. 1 as equivalent to 100, gun-cotton is found to be 120.54, explosive gelatine 154.29, nitroglycerine 183.72, emmensite 236.60, and fulminate of mercury 1229.76. These

* Proc. Nav. Inst. 14, 435; 1888.

theoretical conclusions are said to be confirmed by numerous experiments, some of which are described in this pamphlet.

It is proposed to use this explosive not only in mining, but in a granulated form as a substitute for gunpowder as a propelling agent in guns, for which purpose it is claimed to possess three times the power of gunpowder, while it produces no smoke, does not foul the piece, and is safe against violent blows or shocks.

Its sensitiveness to shocks has been tested by Lieutenant Zalinski with the following apparatus: He fits a stout tube, closed at one end, into an air-chamber, so that the mouth of the tube opens into the chamber, and he places the explosive in the tube and closes the mouth of the tube with a steel plate. Then he introduces compressed air into the chamber until it attains a pressure of 4000 pounds per square inch, or more than 300 atmospheres, when the plate breaks and the explosive is exposed to the impact of this highly compressed air. Under these conditions, nitroglycerine, gun-cotton, dynamite, and gunpowder exploded, but emmensite failed to explode.

The *Pittsburgh, Pa., Dispatch* states that a gun is now being constructed in that city for the American Emmensite Company, with which to demonstrate the value of their explosive. It is to be a smoothbore, 3 inches in diameter and 100 inches long, and is expected to throw a 6-inch (*sic*) shell filled with emmensite from 10 to 12 miles. It is explained that in rifled cannon the shell turns $1\frac{1}{4}$ times in the length of the gun; that this causes a terrific torsional strain, which necessitates a great increase in the thickness of the shell, with a proportionate reduction in the space for the explosive; and that the Emmensite Company return to smoothbores to avoid this trouble, while they rely upon the great power of their explosive to secure the necessary range.—*Ill. Nav. Mil. Mag.* 9, 169; 1888.

Major J. P. Cundill, R. A., H. M. Inspector of Explosives, has reprinted in a separate volume his admirable "Dictionary of Explosives," which has appeared in installments in the Proc. Royal Artillery Inst. for 1887 and 1888. In this work, the explosives treated of are grouped in eight classes, arranged in alphabetical order in each class, and the whole carefully indexed. With each substance is given a brief but lucid statement of its composition, and, when of special importance, of its special properties and method of manufacture, while a succinct historical account and a notice of the general

characteristics precedes each group. The work is an invaluable one to those engaged in the study or use of explosives, its accuracy and reliability being insured from the experience and professional position of its author. From this work we learn that *Roburite** consists of a mixture of ammonium nitrate and meta-di-nitro-chlor-benzene; that *Romite*† consists of a mixture of ammonium nitrate, naphthalene or nitro-naphthalene, and potassium chlorate; and *Securite* consists as a rule of 74 per cent of ammonium nitrate with 26 per cent of meta-di-nitro-benzene, though other varieties have been made which contain the tri-nitro-benzene and the di- or tri-nitro-naphthalenes.

A new variety of "securite" has been prepared by Herr Schoeneweg, which is said to be flameless when exploded, and will, it is expected, be of especial value as a substitute for ordinary blasting powder and other explosives in fiery coal mines. It consists of nitrated hydrocarbons mixed with an oxidizing agent, such as chlorate of potash, and some organic salt which renders the mixture flameless. The substance is not hygroscopic, and is of a bright yellow color, and can be kept for any length of time without undergoing any change. It cannot be exploded by a flame nor by a hot substance, but only by a detonating cap. Recent experiments at Hendon have proved that the new explosive fulfills the anticipations of the inventor, and we understand that the Flameless Explosives Company have undertaken to introduce it to the notice of mine owners and others to whom an explosive of this nature should be welcome. Its power is said to be equal to that of No. 1 dynamite, and it can be manufactured at a less cost. The organic salt which is added to the "securite" to produce this effect has also the property of rendering dynamite similarly flameless when mixed with it.—*Sci. Am.* 58, 263; 1888.

The numerous explosions at various parts of Stockholm (there were thirteen) which occurred during one or two exceedingly hot days in the last week of June, seem all to have been caused by the spontaneous decomposition of explosives. It appears that *romite* was kept at eleven of the thirteen places, and that it has probably also been found at the remaining two, and further, that the explosions in two instances (at Marieberg and Skinnarviken) must have arisen

* *Proc. Nav. Inst.* 13, 575; 1887.

† *Loc. cit.* 574.

through the spontaneous ignition of this same explosive. Further researches into the matter are pending.—*Engineering*, 66, 35; July 13, 1888.

Both in Germany and in France, extensive experiments have been carried out with the object of producing an improved powder which shall be comparatively smokeless* and non-corrosive, and at the same time give higher initial velocity without corresponding increase of pressure.

In Germany, gun-cotton and nitro-lignin have chiefly been experimented with, while in France, much attention has been bestowed upon picric powders.

The French Brugère powder, which is composed of ammonium picrate and potassium nitrate, is said to give high velocities (over 2000 foot-seconds with small arms), and to cause only very slight recoil. Large numbers of cartridges of this powder were ordered for the new Lebel rifles, but it is stated that a recent examination of a quantity of this ammunition that had been stored at Chalons showed that the powder had deteriorated to such an extent that the whole lot had to be condemned.

France is now experimenting with gun-cotton powders, and has already obtained some marvellous results; some reports say velocities as high as 2500 foot-seconds have been reached. The powder is practically smokeless.

The powder with which 2380 foot-seconds was obtained from the Armstrong 36-pounder rapid-firing gun is a German invention. Although not smokeless, the smoke is much less in volume than that from ordinary powder, and is speedily dissipated. The same German experts have perfected a powder for small arms which is said to be absolutely smokeless. This has been adopted as the service powder of the German army. The right to this invention has been secured by the Chilworth Gunpowder Company, in England, and the company announces itself as already prepared to turn out both rapid-fire gun and small-arm powders in quantities as large as are likely to be required by the Government service.

Under the name of Paleina, the *Rivista di Artiglieria e Genio* describes a straw powder invented by a French officer which is stated to be suitable to both military and mining operations, to be smokeless, and to possess remarkable explosive force.

* Vide Proc. Nav. Inst. 13, 593; 1887.

The mode of manufacture is as follows: The straw is first subjected to a process which makes the fibre soft and pliant, and is then washed and triturated in an apparatus similar to that employed in reducing rags to pulp. From these operations the fibre issues in the form of thin sheets, which are cut up and steeped first in a mixture of nitric and sulphuric acids, and then after careful washing to remove the excess of acid, in a solution of saltpetre and dextrine containing pulverized hardwood charcoal; the final product is dried in a current of air.

Paleina, as thus prepared, has the appearance of small disks of cardboard. In the open air it burns slowly and with a blue flame, but when detonated in a confined space it explodes with a force of about three times that of gunpowder. It makes no smoke and leaves no residue.

The straw has the property of absorbing nitroglycerine in a considerable proportion, and then forms an explosive superior to dynamite in power, and relatively safe and easy to handle.—(*Loc. cit.* 375.)

The *Revue Maritime et Coloniale*, 533, September, 1888, states that a new powder which is smokeless, while it possesses all the qualities of the best gunpowder, has been experimented with, and that it is prepared by using carbon from cork in the place of charcoal. By this means the hygroscopicity of the powder is very much reduced.

The exact nature and formula of fulminic acid and its compounds, owing to their extreme unstableness, is, comparatively speaking, little known. The following "Recent Investigations on the Fulminates," by H. N. Warren, offer further contributions to our knowledge of them.

The salt used to conduct the experiments with was silver fulminate. This being dissolved in hot water, and digested with copper filings, was transformed into cupric fulminate; the green salt obtained was dissolved in water and introduced into a tube open at either end, one extremity being closed by means of a porous diaphragm. The salt was reduced by means of nascent hydrogen, according to the usual method, by connecting the same with a small Daniell's cell, the inside of the tube being provided with a platinum electrode connected with the negative end of the battery. In the course of a few hours the whole of the copper had become reduced to the metallic form, and firmly attached to the platinum plate.

The solution obtained being thus freed from copper was next

examined and was found to contain, besides large quantities of hydrogen cyanide and ammonia, distinct quantities of fulminic acid, evidently existing as ammonium fulminate. This was obtained and examined as fulminating silver by digesting with silver carbonate. In every instance an explosive fulminate was re-formed, corresponding to the normal fulminate.

In the next experiment, cupro-ammonium fulminate was obtained by the addition of an excess of ammonia to a solution of cupric fulminate. The deep-blue crystals thus formed were, after being dried by suspending them over sulphuric acid, decomposed by dry hydrogen sulphide. The product consisted, however, chiefly of copper sulphide, with urea and ammonium sulpho-cyanide.

Further, an attempt was made to combine fulminic acid with silicon, by passing a stream of dry silicon fluoride over silver fulminate, kept moist by means of petroleum. Large quantities of silver fluoride were at once formed, and the escaping gas, when collected and ignited, exploded with considerable violence. Although the results obtained from several experiments performed by the same method agree with each other identically, it still remains an open question whether such a compound as silicon fulminate does in reality exist.

Chlorine, iodine, and bromine were also used, but chiefly gave rise to chloropicrin and other bodies of an allied formula. Experiments were also performed with the view of obtaining an ethyl compound, but these require further investigation before speaking definitely of them.—*Chem. News* 57, 255; 1888.

Major Philip Hess states in the *Mitt. Art. Genie-Wesens, Notizen*, 47, 1887, that in extracting the fulminating composition for detonators for analysis, he has been accustomed to loosen the composition by carefully squeezing the caps between boards until the case was somewhat flattened, rounding it out again, and again flattening it. Then by means of a camel's hair brush the contents are completely brushed out on to glazed paper. He finds that detonators will bear a good deal of gradual compression without exploding, and that a cork squeezer may be used for the purpose described above, but it is best to employ a safety-brake with it.

A. von Cettingen and A. von Gernet have repeated the work of Bunsen, Berthelot and Vieille, and also that of Mallard and Le

Chatelier upon the "Phenomena attending Explosions in Gases," making use of instantaneous photography to record the phenomena, and their results are given in a very valuable paper in the *Ann. der Physik u. Chem.* **33**, 586-609; 1888. A rotating mirror was employed with a metallic pointer, to which an electric spark passed when the mirror was in the right position to reflect an image of the eudiometer tube, in which the explosion took place, into a photographic camera. The same spark served to explode the gases. The most sensitive Beernaert plate gave no trace of an image. No results could be obtained by staining the plates with cyanine or with azaline. Eastman's negative film paper, however, gave a faint image. The authors were compelled to sprinkle certain powders in the eudiometer tube. Chloride of copper gave the best results. Plates of the phases of the explosions accompany the paper. The experiments show that the explosion of hydrogen is not accompanied by light. The resulting high temperature, however, causes a disintegration of the glass of the eudiometer tube which produces a certain illumination. Three species of wave motion were observed: first, a fundamental wave, which is entitled Berthelot's wave; second, more or less parallel secondary waves; third, polygonal waves of smaller amplitude. The photographic image of the electric spark which was received upon the same plate as that of the explosion, enabled the authors to estimate the velocity of the explosion. The result obtained, 2800 meters per second, is of the same order of magnitude as that obtained by Berthelot. The authors agree in the main with Berthelot's conclusions, differing only in reference to the beginning and the end of the explosion. They explain the secondary waves on Bunsen's hypothesis of the reflex action of waves due to successive explosions produced by the electrical spark. They therefore term these Bunsen's waves.

Many experiments have proved that the velocity of sound obtained by observing from a known distance the instant of the discharge of a rifle and the arrival of the sound of the explosion at the place of observation, is frequently greatly in excess of the normal rate of propagation of sound. To determine the cause of this increase and the laws which govern it, a series of experiments have recently been carried out by M. Journée, who has presented a memoir on the subject to the French Academy of Science. His experiments show that if a bullet is fired from a rifle against an iron plate, then so long

as the velocity of the bullet is in excess of the normal velocity of sound through air, the noise of the explosion and of the bullet striking the plate reach an observer, situated in the plane of fire behind the plate, at the same instant. If the distance of the plate from the rifle is increased till the velocity of the bullet before reaching it is reduced below that of sound, then the noise of the explosion reaches an observer before that of the shock against the plate. Hence the author concludes that the bullet, so long as its velocity is greater than the normal velocity of sound, is the seat of a sonorous disturbance resembling in character that due to an explosion, and this view he has substantiated by further experiments.—*Comptes Rendus*, 106, 244-247, Jan. 23, 1888.

The valuable paper by Sir Frederick Abel, on "Accidents in Mines," hereinbefore referred to,* is an outgrowth of his studies and researches as a member of the Royal Commission appointed in 1879 to deal with this subject, and as these accidents are due to a great variety of causes, and since each of these is treated of as exhaustively as the space permits, there is much useful and valuable matter which is not germane here, while the general results arrived at in regard to matters such as explosions due to coal-dust-laden air, and to those caused by explosive gaseous mixtures moving with high velocities becoming inflamed by safety lamps, have already been referred to in these Notes.† Hence we shall notice only that part of the paper which deals with the use of explosives in mines.

Formidable danger frequently attends the employment of blasting powder in coal mines on account of the flame which generally attends, though to a very variable extent, the firing of a shot tamped in the usual manner, and especially on account of the larger volume of flame which is projected to a considerable distance, either when a blast-hole is overcharged, or when the preponderating strength of the material operated upon gives rise to what is termed a "blown-out shot," the tamping being projected from the hole like a shot from a gun. These sources of danger were recognized long before any views were advanced regarding the possible connection of coal dust with mine explosions, and the precautions enacted for ascertaining the absence of any important contamination of the air at the working place with fire-damp before shots were fired, and for reducing to a

* Proc. Nav. Inst. 14, 440; 1888.

† 8, 308; 12, 427; 14, 439.

minimum the number of lives subject to possible danger when shot-firing was carried out, are well known.

Proposals have, from time to time, been considered by the inspectors of mines and others, for either abolishing the use of powder in fiery mines, or for greatly restricting its application by the imposition of more or less stringent conditions. When the Royal Commissioners gave this subject their attention and collected evidence bearing upon the dangers of shot-firing in mines and the possibility of dispensing with the practice, they were led to the conclusion that the abolition, or even the very considerable restriction of shot-firing as practiced under the existing laws, would be incompatible with the working of a large number of pits, except at a prohibitive pecuniary outlay. Realizing most fully, on the other hand, the dangers that frequently attend the use of powder in coal mines and the extreme difficulty of effecting any important diminution of those dangers, they devoted much attention to the question whether it might be possible to discover any powder substitute, or any method of using such substitute, which would secure immunity from danger due to the presence of coal dust and fire-damp in the localities where blasting had to be carried on.

From time to time assertions have been made as to the supposed comparative safety of different explosive agents more or less analogous in composition to blasting powder. It is not difficult to put the validity of such assertions to the test by chemical examination of the particular explosive preparations, and it may be confidently maintained, from the experience which the Royal Commission and the author individually has acquired of preparations of this class, that there are but very few practically useful explosive agents of the gunpowder type which possess any advantage in point of comparative safety over ordinary black or blasting powder.

The employment of powder in the compressed form, which has of late years become very extensive, presents important advantages in point of convenience and general safety of handling, but does not in any way affect the dangers in reference to use in coal mines, inherent in an explosive agent, the employment of which is liable at any time to be attended by the production of considerable volumes of flame. Attempts were made, in the earlier days of the history of gun-cotton, to apply that material as a blasting agent in coal mines, but the circumstance that its explosion is attended by the development of a large proportion of carbonic oxide renders it inapplicable in this

direction, as its explosion (even by detonation) is liable, on that account, to be attended by the production of a considerable volume of flame. Finely divided gun-cotton may be readily incorporated with the proportion of a nitrate (saltpetre, or barium nitrate) necessary for the complete oxidation of its carbon, the generation of carbonic oxide being thus prevented or reduced to a minimum; and such preparations as nitrated gun-cotton, tonite or potentite, produced by compression of mixtures of this class, have found favor to some extent in drift work, or in the blasting of stone over and underlying coal seams, as being more powerful than powder; but their explosion is by no means unattended with the possibility of the development of flame. In this respect nitroglycerine preparations are undoubtedly superior. This explosive agent contains a proportion of oxygen slightly in excess of that required for the complete oxidation of its constituent carbon, hence its perfect explosion is unattended by the development of inflammable gas. The most common form in which nitroglycerine is commercially employed is as dynamite. When exploded by detonation, the heat developed by the metamorphosis of the nitroglycerine raises the mineral matter present to a bright red or white heat, and the detonation of this preparation is always attended by the appearance of sparks in the dark. But if even the undiluted nitroglycerine is exploded in a shot-hole, the high temperature has the effect of raising to incandescence, particles of the tamping employed, or of the coal or stone exposed to the highly heated gases and vapors developed, so that under any circumstances sparks would be liable to be projected on the firing of a nitroglycerine charge. The same holds good with any of the nitroglycerine preparations known in commerce, such as lithofracteur, blasting gelatine, or gelatine-dynamite; moreover, flame in more or less abundance may be produced by the explosion of some nitroglycerine preparations, the composition of which includes proportions of inflammable materials.

That the heat to which very finely divided solid particles may be raised, by exposure to the highly heated products of detonation of nitroglycerine preparations, is sufficient to determine the ignition of an explosive fire-damp mixture, has been amply demonstrated by experiment, and it is even possible that sparks sufficiently hot to produce that result may be carried to some distance by the blast of heated gases projected by a shot, and thus reach places at some distance from the shot-hole where gas may have lodged.

The author's long connection with the study of explosives and their application to every variety of use, naturally led to his special devotion of much attention to this branch of its investigations; and the first idea bearing upon the occurrence of casualties in coal mines which suggested itself to him was to apply the principle of most complete explosion, or detonation, of one or other of the so-called "high explosives" (chemical compounds highly susceptible of sudden metamorphosis into gaseous products or vapors) in conjunction with the method first devised by him in 1873, and communicated in that year to the Royal Society, of distributing the operation of the force developed by small charges of the explosives over a considerable area, through the agency of a comparatively large volume of water, by which the charge is enveloped.

The principle of suddenly transmitting the force of detonation of a charge of explosive uniformly in all directions, by completely surrounding with water the charge to be detonated, had already been successfully applied by him to the conversion of an ordinary shell into a projectile operating with the destructive effects of a shrapnel shell, and to several other purposes, and it occurred to him that by applying the same principle to the charging of a shot-hole, the effect might be not only to modify the destructive action of a high explosive, and thus to attain a comparatively moderate splitting or rending action instead of powerful disintegrating effects, but also to accomplish the extinction, through the agency of the water envelope, of any incandescent particles or sparks, and perhaps flame, projected by the exploding charge, the water being thrown forward together with them in a finely divided condition. It soon afterwards came to the author's knowledge that Dr. McNab had previously put into practical execution the idea of extinguishing the flame of a powder charge projected from a shot-hole, by inserting a cylinder filled with water over the charge and confining it by a small amount of tamping. The application of water in this way, in conjunction with powder, was also expected by Dr. McNab to effect important economy of time in blasting operations, by diminishing the persistency of the smoke through the solvent action of the water, thereby enabling men to return to work in a comparatively short space of time after the firing of shot. The latter result appears to have frequently been attained to a useful extent, but experience showed, on the other hand, that sufficient reliance could not be placed upon the extinguishing effects of water thus applied in conjunction with powder being

sufficiently exerted to afford reliable security against the ignition by the flame from a blown-out powder-shot, of an explosive gas mixture, or of dust thickly suspended in air containing a small proportion of fire-damp. A series of experiments indicated, however, that water-tamping, as first suggested by Dr. McNab, used in conjunction with a high explosive such as dynamite, afforded very considerable, if not absolute, security against accidental explosions under the conditions just now specified.

An exhaustive series of experiments was instituted, chiefly in South Wales, with a view to ascertain whether perfect security against ignition of explosive gas mixtures, and of coal dust thickly suspended in air containing a small proportion of coal-gas or fire-damp, was secured by the application of high explosives in conjunction with water in the way suggested by Abel, the charge of explosive being enclosed on all sides by water, with or without the additional use of superposed tamping. The results appeared to justify the conclusion that the so-called water-cartridge, employed in conjunction with a high explosive, could be relied upon to afford security against accidental explosions during shot-firing in the presence of explosive gas mixtures, or of very inflammable coal dust thickly suspended in air containing some small proportion of fire-damp. The results obtained for the Royal Commission have been confirmed by experiments of a similar nature pursued by others in this country, by experimenters in Saxony, and by members of the Prussian Fire-damp Commission. In the course of these various experiments it has been found that the particular form of dynamite to which the name *gelatine-dynamite* has been given, is especially suitable for employment in conjunction with water, as it retains its explosive properties unimpaired under these conditions, and may, in blasting operations, be placed quite unprotected, either in a shot-hole which is filled with water, or in a cylinder full of water of suitable dimensions for insertion into the hole. In constructing a water-cartridge there is not the least necessity for employing any device for keeping the explosive in such a position that its circumference is surrounded equally on all sides by the water; it suffices simply to insert the charge with its waterproofed fuze or wires attached, into the blast-hole direct (if the latter is in perfectly solid stone or coal and in a suitable position), or into the cylinder of thin sheet metal, varnished paper or membrane which is filled with the water; it is best, however, to insert the charge nearly to the bottom of the water, so as to utilize the tamping effect

of the greater part of the column. The liquid is retained by a wooden or cork plug, through which the fuze or conducting wires pass, and tamping is applied over this after insertion of a tuft of hay or other suitable padding material.

The work done in coal by a high explosive, through the agency of a column of water which encloses it (or "water-cartridge"), is different in character to that accomplished by the same charge used in the ordinary manner. Instead of exerting a crushing action immediately round the charge, whereby much small coal is produced and no large amount of displacing work performed, the force being distributed over the whole area of the water column, its action is thereby greatly moderated, and the coal is brought down in large masses, the work done extending over at least as large an area as that of the best powder-shots.

In applying this system as a safeguard against accidental ignition of coal dust or fire-damp mixtures, the quantity of water used should at least amount to four times the volume of the charge employed.

It has come to the knowledge of the author that, in a colliery where a serious explosion recently occurred, so-called water-cartridges were in use, in which, when the charge of explosive had been inserted, very little room was left for water. From the published account of the evidence given at the inquest, it appeared to have been affirmed that Abel's water-cartridge had been used at a great expense, and it was left to be implied that the calamity was due to confidence being falsely placed in the safety to be ensured by its employment.

The practical development of the principle of applying water in conjunction with high explosives cannot fail to be fruitful of improvements in the mode of operation, as indeed it has already been; thus, in order to avoid a loss or diminution of the safeguard furnished by the water from the escape of the liquid through channels or fissures in the shot-hole, or through leaks in the water-cylinder or cartridge, it has been proposed by Messrs. Heath and Frost to dissolve sufficient size or glue in the water, warmed for that purpose, to make it solidify on cooling in the case or shot-hole to a sufficiently stiff jelly to prevent such escape. Again, the experiments carried out for the Commission with water-cartridges led to the observation that a considerable proportion of the water was driven forward in a body instead of being dispersed in a very fine state of division, by the force of a blown-out shot, and a suggestion was consequently made

for the employment of the water in a different manner, which was worked out by Mr. Galloway with most successful results, so far as related to the extinction of flame and sparks from a blown-out shot. By distributing the water through a very porous body (such as sponge or moss), and thus effecting an initial interruption of continuity of the mass of liquid placed over the shot, its thorough dispersion in a very finely divided condition is ensured, and its extinguishing power is greatly increased. It was found, in a number of experiments at the Dowlais works, that in holes of 2 inches diameter, the placing of 9 inches of loose tamping of moss soaked with water over a 4-oz. charge of dynamite sufficed to prevent the ignition of dust-laden air containing coal-gas by the blown-out shot, and that such a shot produced with $2\frac{1}{2}$ oz. of dynamite, the charge being covered with only 4 inches of loose moss and water-tamping, failed to fire an explosive gas mixture. A number of comparative experiments demonstrated that the water-cartridge was on an equality with moss and water-tamping in preventing the ignition by blown-out shots produced with dynamite, gun-cotton, tonite and gelatine-dynamite, of a dense cloud of highly inflammable dust suspended in air containing a small proportion of coal-gas (the cloud produced under the same conditions being invariably inflamed by an ordinary blown-out dynamite shot); but they proved that the water-cartridge did not afford that absolute security against the ignition of an explosive gas mixture by a blown-out dynamite shot that, so far as a number of consecutive experiments showed, was attained by the comparatively simple moss and water-tamping, which can be applied without difficulty even in holes having an upward inclination.

The water-cartridge employed with various high explosives in such a way as to produce blown-out shots in the presence of coal dust and gas, has been made the subject of official experiment in Prussia and Saxony, and apparently with results as satisfactory as have now been obtained in different mining districts in this country; it may be considered to have been conclusively established that the application of water in the shot-hole in one or other of the ways indicated, in conjunction with the use of high explosives, affords most important security against accidents in blasting stone or coal in mines where dust and fire-damp co-exist.

It may be well again to emphasize the fact that neither the water-cartridge nor water-tamping applied in the manner in which it has been found so thoroughly efficient in conjunction with high explo-

sives, affords any safeguard against explosions arising from the presence of fire-damp, or coal dust associated with fire-damp, in mine workings where blasting is carried on, if powder, or any explosive agent analogous in its composition and mode of explosion to powder, be employed in conjunction with them.

Suggestions have been made to use in conjunction with powder, or as tamping over the charge, certain solid preparations which will evolve gases or vapors, when exposed for a sufficient period to heat, capable of extinguishing flame, the idea being that the heat developed by the explosion of the charge would accomplish the desired results, and that the dangers arising from blown-out shot might thus be guarded against; but the authors of these suggestions have not realized the importance of time as a factor in the establishment of chemical changes by the action of heat, and the consequent impossibility of gases and vapors being evolved, in the desired manner, within the exceedingly brief period during which the materials applied are exposed to heat. The Commission, at the author's suggestion, had experiments carried out for the purpose of ascertaining whether condensed (liquefied) carbonic acid could be applied in suitable tamping vessels, in conjunction with high explosives, as an extinguishing agent, but the results were not sufficiently encouraging to warrant perseverance in this direction of experiment.

Some attention has been attracted since the publication of the Commission's final report, by a safety blasting cartridge brought forward by Dr. Kosmann, of Breslau, which depends for its action upon the rapid development of hydrogen under high pressure from very finely divided zinc, by the action of sulphuric acid (enclosed in one compartment of a compound vessel of glass). The acid is intended to have access to the zinc after the apparatus has been fixed into the shot-hole, in such a way that the gas, which is said to speedily attain a high degree of compression, shall exert its force upon the stone or coal. The cost of each shot is stated to be only small, but the description scarcely warrants the view that the arrangement is a practically efficient one, and no account of successful experiments with it in actual blasting operation has yet reached the author.

Various proposals to apply compressed air to the getting of coal have been put forward, among which was one by Mr. Samuel Marsh, of the Clifton Colliery, Nottingham, to the practical development of which Mr. Ellis Lever devoted much trouble some years

ago, but no really satisfactory results appear to have been attained with it.

The considerable increase in volume which caustic or quick-lime rapidly undergoes during the slaking process (or its conversion into hydrate by union with water), was already many years ago regarded as a source of power which might be available in lieu of powder for the bringing down of hard coal; but repeated attempts to utilize it met with no practical success until Messrs. Sebastian Smith and Moore, about six years since, made two important steps in advance. In the first place, by reducing freshly burned fat lime of high slaking power to powder, and converting this into cylinders by applying powerful pressure, they obtain the lime in an exceedingly compact form, which enabled them to utilize the full diameter of a drilled shot-hole, and which rendered the material less liable to air-slaking than when in lumps. In the second place, using the heat developed by the slaking to generate and superheat steam, they were able to supplement to an important degree the force exerted by the expanding charge of lime. The author then details the results which have been obtained in the use of the lime-cartridge, and notes some of the disadvantages which are held to accompany it.

Scribner's Magazine, 3, 563-576, May, 1888, contains an article by Charles E. Munroe, on "Modern Explosives," in which the author has sought to present, in a popular and yet precise way, the theory of explosion, and to describe the characteristic properties and method of use of some of the more typical explosive substances. The author calls especial attention to this article, as it shows that he does not endorse many of the statements which he collates in these Notes.

The paper is well illustrated, principally from photographs and objects prepared at the Torpedo Station. The illustrations of the effects produced by detonating gun-cotton on iron plates show that the theory which he has presented in these Notes* is confirmed by further experiments, for, as shown, he has bored holes of continually increasing diameter and depth in gun-cotton disks until he has pierced one completely with a hole two inches in diameter, and on detonating these on the iron plates he has obtained deeper and deeper indentations in the plates, until, when using the completely perforated gun-cotton disk, he has completely perforated the plate.

* Proc. 11, 110; 1885, and 13, 594; 1887.

This theory is further supported in a paper by the same author in a paper published in *Proc. Newport Nat. Hist. Soc.* No. 6, 18-23; 1888, entitled "On certain Phenomena produced by the Detonation of Gun-cotton." He used a can such as is used for canning fruit and vegetables, placed a disk of gun-cotton in it, filled the can with sufficient water to just completely cover the disk, placed the can on an iron beam, and detonated the gun-cotton by means of a dry priming disk. The can was of such a diameter as to just receive the disk, and the end of the can in contact with the beam was the one through which the can had been filled with its fruit, and as is the case with such cans, the end had a sunken circular channel let into it, and an irregularly shaped mass of solder at the center of the face which was raised above the surrounding surface. On examining the face of the iron beam on which the detonation took place, an impression of this end of the can, with all the depressions and elevations having precisely the same value as in the original, was found to have been exactly reproduced in the iron of the beam. This is well shown in a photo-stereotype attached to the paper.

The author has also succeeded in obtaining "Wave-like Effects produced by Detonating Gun-cotton," by using a tin vessel with a smooth bottom in which to hold the explosive. The can in this case had a diameter much larger than that of the gun-cotton disk; the disk was placed on one side of the can so that the cylindrical surfaces were tangent, and the can was filled with water and detonated on an iron beam just as described in the last experiment. On examining the impression produced on the beam there was found, as was to be expected, a deep impression under the area occupied by the gun-cotton, but, as was not to be anticipated, *the impression extended less deeply quite to the extremity of the area marked by the base of the can.* But what was yet more remarkable was that beneath this crescent-shaped space between the peripheries of the disk and the can which had contained only water, *two sets of breakers had been produced in and remained fixed in the iron,* the crests of the waves being turned outwards. The exterior set of breakers consisted of waves which were easily visible to the naked eye and sensible to the touch, and their average wave-length was found to be closely 1.5 millimeter. The author hopes to be able by this method to distinguish between different explosive substances, and to learn more regarding the nature of explosive phenomena and the way in which

the energy is propagated. A description of the experiment appears in *Am. Jour. Sci.* **26**, (3), 49-51, July, 1888, with diagrams showing the method of experimenting, and an exquisite photo-stereotype of the iron beam.

The theory which we have offered regarding the way in which the indentations are produced by gun-cotton on metal plates is strongly supported by M. P. F. Chalon, in *Le Genie Civil*, in an article entitled "Mining without Tamping," and he extends the theory to the phenomena taking place in a drill-hole. We are indebted to him for a copy of this article, which we reserve for a later date.

"Les Explosifs Modernes," by P. F. Chalon,* is a theoretical and practical treatise prepared for the use of civil and military engineers and miners, which appears in the form of a large octavo of some four hundred pages, with upwards of one hundred and sixty figures intercalated in the text. The matter is well arranged and so treated as to make this an excellent manual as well as a work of reference. While sufficient space is given to the properties of the substances which may be employed in the manufacture of explosives, to the methods of manufacture and properties of the more important explosives, to the methods of analyzing and of testing the force of these explosives, and to their uses in peace and war, yet some fifty pages are devoted to the legislative acts in Austria, England, France, and the United States, which regulate the manufacture, transportation, storage and use of explosives in these countries. This information, which is so important, but which it has hitherto been difficult to gain access to, apart from the other merits of the work, makes this book a necessary one to possess.

"La Dynamite de Guerre et le Coton-Poudre," by Max. Dumas-Guilin,† treats of the manufacture, transportation, storage and use of these explosives according to the orders and regulations which govern the French army concerning them. As, besides giving these regulations at length, its matter is largely drawn from the courses of instruction at *l'Ecole de Guerre* and *l'Ecole du Genie de Versailles*, the work has almost the authority of a Blue Book. As might be expected from this, we find minute and detailed descriptions of the methods to be followed in the service during storage, transportation,

* E. Bernard et Cie., Paris, 1886. † Henri Charles-Lavauzelle, Paris, 1887.

and use of the explosives mentioned, both in times of peace and war; the treatment of the topics of military mining and the destruction of material being especially full and explicit. The book contains about four hundred small octavo pages, with about fifty figures in the text, and is of a convenient form for a manual for use in the field. As will be seen from the description, the book is one which commends itself especially to officers of the navy and army.

M. P. F. Chalon also presents "Le Tirage des Mines par l'Électricité,"* in the form of a small octavo of two hundred and seventy-six pages, with ninety figures and numerous tables. The book deals both with the theory and practice of firing mines by electricity, and describes at length the different blasting caps and detonators, the electrical firing apparatus, both batteries and machines, and the methods of wiring mines for large blasts.

"Die Elektrische Minenzündung," by Karl Zickler,† is an octavo pamphlet of one hundred and sixteen pages, with sixty figures, and with tables, which deals more briefly with the subject treated of by Chalon in the last mentioned book.

R. Gaertner, of Berlin, announces the publication of "Die Fabrikation von Chlorsauren Kali und anderen Chloraten," by K. W. Jurisch, Ph. D.

* Baudry and Cie., Paris, 1888.

† F. Vieweg & Sohn, Brunswick, 1888.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH,
JANUARY, 1889.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XIX.

U. S. Letters Patent No. 393,107, November 20, 1888, have been granted W. E. Hicks, of Brooklyn, N. Y., for a machine for the throwing of projectiles filled with high explosives, in which he avails himself of the so-called centrifugal force as his projecting agent. The machine consists of two steel disk-wheels placed concentrically side by side upon a shaft. To this shaft a pulley wheel is attached, the revolutions of which give a velocity sufficient to discharge projectiles with the necessary force. The projectiles are placed in pairs on the opposite sides of the periphery of the wheel, and thrown two at a time, one from each side of the wheel, by pulling a lanyard. This unlocks an automatic apparatus holding the projectiles, and releases them at any given point in the revolution of the wheel, so that they can be thrown at any angle desired between the zenith and the horizon. The whole apparatus is set upon a turn-table, so that it may be trained in any direction. The carriers are so arranged as to fly upwards at the instant of discharge, and thus to counteract the centripetal tendency of the curvilinear trajectory. The initial velocity is, of course, limited by the tensile strength of the steel firing chambers. The application of this force to the throwing of projectiles is older than the time of David, and attempts to apply it to modern uses have been

* As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. *Address Torpedo Station, Newport, R. I.*

made by Winans, and probably by Brunel and others. One peculiarity of the gun, or engine, as it might perhaps more properly be called, is its comparative noiselessness. There being no expansion of gases, and no vacuum, there is no report of any kind, the only sound being the whiz of the shell as it passes through the air. There is neither flash nor smoke, report or recoil, and there is nothing to apprise an enemy of the whereabouts of the gun, and the destroyer might come in the midst of an enemy unseen and unheard. It is hoped that a thorough trial of this new gun will be made from which data may be obtained concerning its efficiency, range, and practicability as a weapon of warfare.

The combination shot and shell designed to be used in this engine is of regulation shape, having a solid steel head for the purpose of producing the greatest penetration upon impact. It is provided with a steel rod or percussion striker, extending through the center, one end of which is adjusted in the apex of the ogival head, while the other end rests against a percussion primer, which upon impact explodes the charge of explosive, thereby producing a double blow, by impact of the shot and by the subsequent explosion.

The shot can also be exploded submarine, being provided with a device which will produce an explosion in case the target should be missed. Should that target be a ship, the effect would not then be wholly lost.

The apparatus devised by Mr. Hicks is illustrated, and the data used in determining its theoretical efficiency is given in the *Army and Navy Jour.* 26, 302, December 15, 1888, and also more fully in the *Sci. Am.* 59, 399-400, December 29, 1888.

U. S. Letters Patent No. 359,491, March 15, 1887, have been granted Louis Bagger, of Washington, D. C., for a primer for igniting explosives, and for which he makes the following claims:

1. A primer for igniting combustible or explosive compounds, the igniting charge of which is composed of potassium, or an equivalent material having a stronger chemical affinity for oxygen than the affinity which exists between oxygen and hydrogen in the formation of water, whereby such primer is ignited in contact with water.

2. The combination with an explosive shell, of a primer or igniting device composed of material possessing a stronger chemical affinity for oxygen than the affinity which exists between oxygen and hydrogen in the formation of water, whereby the shell is exploded on contact with water.

3. The combination with an explosive shell, of a primer or igniting device composed wholly or in part of the metal known as "potassium," whereby the shell is exploded on contact with water.

4. The combination with an explosive shell and a primer therefor, having an igniting charge composed of potassium, or an equivalent material having a stronger chemical affinity for oxygen than the affinity which exists between oxygen and hydrogen in the formation of water, of an air and waterproof covering for protecting such primer, as set forth.

5. The combination with a percussion primer of any desired construction, of an igniting device composed of material possessing a stronger chemical affinity for oxygen than the affinity which exists between oxygen and hydrogen in the formation of water, whereby such primer is exploded on contact of the igniting device with water.

6. The combination with a percussion primer of any desired construction, of an igniting device composed wholly or in part of the metal known as "potassium," whereby the primer is detonated by contact of the igniting device with water.

7. The combination with a percussion time-fuse of any desired construction, of an igniting device composed of material possessing a stronger chemical affinity for oxygen than the affinity which exists between oxygen and hydrogen in the formation of water, whereby such fuse is fired on contact of the firing device with water.

8. The combination with a percussion time-fuse of any desired construction, of an igniting device composed wholly or in part of the metal known as "potassium," whereby on contact of the potassium with water the fuse is ignited, as set forth.

9. A fuse adapted to be ignited by contact with water, consisting of any suitable combustible material confined in whole or in part within a tube or other envelope, and provided with a primer or igniting device whereby the fuse is ignited, being composed of material possessing a stronger chemical affinity for oxygen than the affinity which exists between oxygen and hydrogen in the formation of water.

10. A fuse adapted to be ignited by contact with water, consisting of any suitable combustible material confined in whole or in part within a tube or other envelope, and provided with a primer or igniting device inclosed within or covered by an envelope of suitable material, said primer or igniting device whereby the fuse is ignited being composed wholly or in part of the metal known as "potassium."

Mr. Bagger states that the invention relates more particularly to

an improved method of igniting the explosive charge in shells and torpedoes through the direct action of the water into which the shell may drop or the torpedo be immersed, and that it may also be used with advantage in life buoys, life rafts, and other life-saving apparatus ; for igniting signal lights, sounding high-water alarms, and for numerous other purposes where it is desired to ignite an explosive charge or other combustible material instantaneously through the direct action of water, which may be either salt or fresh, so that the invention is equally adapted for use on the open ocean and in inland waters.

Of its advantages, he states that it may be applied to all kinds of explosive shells equipped with either percussion primers or time-fuses. Where the primary object is to explode the shell at the moment of contact with the ship or other object aimed at, the improvement assumes the form of an auxiliary device for causing the explosion of the shell if it drops into the water. Experience having shown the difficulty of squarely hitting, with heavy ordnance, a movable target, whereby the shell without exploding simply sinks to the bottom, by providing a shell with this auxiliary fuse or "water primer," as he calls it, while it does not in the least interfere with its explosion by percussion if it does strike the object aimed at, when it fails to explode and simply drops into the water it will, the instant it reaches the water, explode through the action of the auxiliary fuse, scattering its fragments over a large area of water surface, and subjecting objects at a considerable distance to the disastrous effects of the air-wave or concussion resulting from the explosion of a charge of dynamite or other powerful explosive with which it may be charged. This object is accomplished by providing the shell with an auxiliary fuse, and priming it with material possessing a stronger chemical affinity for oxygen than exists between the two components of water. Of such materials, potassium he considers particularly adapted to his purpose, owing to its excessive chemical affinity for oxygen and the readiness with which it can be obtained in commerce.

The so-called "water-primer" consists of a thin plug, disk, or film of this material, or its equivalent, introduced through a hole bored through the shell to the chamber containing the explosive material, which is charged with gunpowder, gun-cotton, or any suitable explosive. The hole and fuse are then covered or plugged with a thin disk or film of potassium, which, to protect it from oxidation, may be placed in a glass tube open on the lower side, where it is in contact

with the powder in the fuse. If the shells are to be stored for any considerable length of time before use, a thin film or coating of paraffine, petroleum paste or similar material may be applied to the under side of the disk of potassium, effectually preventing oxidation.

Other devices may be employed for protecting the water-primer from the action of the atmospheric air, viz. a plug fitting air-tight and bearing with its inner end against the primer inserted in said aperture. On firing, this plug is to be removed, or it may be made of material which will be fractured by the explosion when the shell is fired, or of some soluble material which will dissolve instantaneously when the shell comes in contact with the water. And, again, the potassium primer may be protected by a covering in the nature of a plaster, which may be removed on firing, or composed of material which will instantaneously dissolve when the shell touches the water. For practical purposes, a piece of canvas treated with a composition of paraffine, rock-oil, and cement answers admirably and protects the water-primer indefinitely. On firing, this plaster can readily be torn off, so as to expose the primer to the action of the water.

The fuse-channel may be made to communicate with the percussion primer instead of the chamber containing the charge, and the primer can also be used in combination with a time-fuse by drilling a hole communicating with it, showing that the device may be used in combination with either a percussion or time-fuse, instead of in direct combination with the body of the shell.

When the shell is to be used, but not before, the potassium primer is exposed by breaking or removing its envelope. Should the shell drop into the water, the chemical action of the exposed primer results in the immediate explosion of the shell the moment the primer touches the water, the heat developed being more than sufficient to ignite the fuse and explode the charge within the shell even before this has been completely immersed in the water. However, by graduating the thickness of the primer disk, the fuse may be made so that explosion will not take place until the shell is fully immersed.

In its application for the exploding torpedoes the fuse may conveniently be made of a piece of gas-pipe filled with any suitable material for a fuse, the upper part of which is made of glass or other fragile material to be filled with a suitable quantity of the water-primer; Mr. Bagger preferring a tube similar to a barometer tube, sealed at the top, and filled, or partially so, with potassium, care being taken to provide a water-tight connection. When a vessel passes over it, touching the

glass tube, the tube is fractured, the potassium exposed, and the instantaneous explosion follows. If the torpedo and fuse are made properly, *i. e.* water-tight, the torpedo may remain immersed for any length of time without the least deterioration. It is difficult to pick up these torpedoes by "torpedo finders," the least touch of a pole breaking the glass end of the fuse and producing explosion.

These are but a few of the many purposes this invention may be applied to—igniting Roman candles, or signal lights on life-rafts, through direct action of the water the moment the buoy is thrown therein, or used in shells adapted to float and primed with one of his water-primers so that the shell will take fire on striking the water, and when its contents are ignited, illuminating the surrounding neighborhood. Other purposes, for war as well as in peace, readily suggest themselves.

It will be noticed that Holmes, in his self-lighting, inextinguishable signal light (a full description of which will be found in *Ding. Poly. Jour.* **201**, 203–205 ; 1871), avails himself of this principle, though he employs calcium phosphide. In this connection we call attention also to these Notes, *Proc. Nav. Inst.* **11**, 770–771 ; 1885.

Capt. E. L. Zalinski has invented a shell for high explosives which it is claimed may be used with safety. This shell has a double casing, each of ordinary cylindro-conoidal shape; but the outer is struck with a sharper ogival, so that the two casings are separated in front by an air space, and a collapsible head is formed. In the nose of the inner casting is an elastic cushion of rubber, loose asbestos, or some kindred substance. The bursting charge is built up in the body of the shell as follows: In the interior is a core-cylinder formed by a casing of highly alkaline asbestos paper, with a diameter equal to about one-seventh the diameter of the shell. This cylinder is filled with some very sensitive explosive, such as dynamite, and in the base is a detonator actuated by an electric fuse. A substance such as nitro-gelatine, more powerful but less sensitive than dynamite, is used to fill up the shell; but between it and the inner casing of the shell there is asbestos paper, made strongly alkaline. These two paper envelopes absorb any free acid and serve to protect the charge from the action of external heat. Over the charge, and just in the rear of the elastic cushion, is placed a disk or segment of highly camphorated nitro-gelatine, or other similar compound not very liable to explosion by concussion. When the projectile strikes the object, the charge is not

fired by the impact, but the collapsible head actuates an electric arrangement which explodes the detonator, instantaneously or after a fixed interval, as may be arranged. The detonator explodes the dynamite, which in its turn acts as a detonator to the nitro-gelatine. The arrangement in the front of the projectile effectually prevents the concussion of impact from exploding the charge, which is thus fired from the rear, and the maximum effect produced. Small batteries are contained in the base of the shell, and in connection with them are electric primers, several being made use of in order to insure explosion. The circuits are not closed until the head of the shell collapses. The primer consists of two parts capable of being pressed into electric contact by the action of a spiral spring; in loading, however, these two parts are held away from each other by detents. On firing, these detents are held up to their work by the fluid pressure of the propelling agent, which enters through holes in the primer, as long as the projectile is in the bore. When the latter leaves the bore, the gas or air escapes out of the primer, the detents can no longer hold back the spiral spring, which brings the two parts of the primer together and closes this part of the circuit. It will thus be seen that the detent in the primer is merely a safety arrangement to prevent a premature explosion. When the head is collapsed by impact the circuit is completed, and the primer either fires the shell at once or lights an adjustable length of fuse composition, which can be made to explode the shell at any time-interval after impact. If the projectile falls into water, the concussion will not be strong enough to collapse the point of the shell, and the battery already referred to will not act. It is, in fact, desirable that the projectile shall have time to enter the water some distance, so as to get beneath a hostile ship before the explosion takes place. For this purpose one or more "delay action" batteries are provided. When the circuit-breaking arrangement in the primer above described is closed, the circuit of the cells of these batteries is completed; but no current passes, as one cell is left dry. This cell is provided with a cover which is broken on discharge, and which protects it against moisture until the projectile is fired. When the latter falls into the sea the water enters this cell, which becomes "alive," and the current passes to the detonator.

It has been attempted to impart rotation to the projectile of the pneumatic dynamite gun by screwing into it a "guiding tail," consisting of a spindle with vanes at the end. Zalinski proposes to make

use of this spindle as follows: When the gun is fired, the air causes the spindle and shot to rotate together. When the projectile strikes the water the latter stops the rotation of the vanes, but that of the shell still continues, owing to its comparatively smooth surface; the spindle is therefore screwed out. This action is utilized to actuate either an electric or percussion fuse, as follows: Holes at right angles to its axis are bored through the screwed socket that receives the spindle-head, and in these pins can work. When the spindle-head is home, these pins are pressed outwards against the action of an antagonistic spring, which causes them to fall back into the socket when the spindle is removed. In the electric fuse, when the pin goes back into the socket, electric contacts, previously held apart by it, come together and complete the circuit. In the percussion fuse, a similar pin holds back a hammer from a detonating patch of composition. When the pin releases the hammer, the latter is urged forward by the action of a spiral spring, and explodes the charge.

In shells containing high explosives, both a base and a nose fuse should be used for greater certainty of action. In the base fuse a horse-shoe magnet, with its armature to the front, is made use of. Round this magnet insulated wire is coiled, and the ends are in connection with a primer. When impact takes place the armature is torn off and urged forward, and an inductive current passes round the wires and fires the primer. As an additional safeguard, the front of the armature is formed into the shape of a hammer, which impinges on a patch of fulminate. The same principle is applied to the nose fuse, except that the armature is fixed, and the magnet is pushed backward from it by the action of a spindle to which the magnet is attached, and which passes through the armature and projects at the nose of the shell. In this case also an induced current is made to fire the primer.—*Industries* 5, 579-580; 1888.

The Forum 6, 370-381; 1888, contains a most entertaining article by Park Benjamin, entitled "The New System of Naval Warfare," in which he takes a very sanguine view of the part which Mefford's gun is to play in future wars.

The *New York Herald* of June 16, 1888, states that for some time past experiments have been in progress at the Torpedo Station, Newport, R. I., with a new and powerful explosive which seemed suitable for use as a bursting charge for shells to be fired from heavy guns.

A firing test to determine its availability for this purpose was recently made at the naval ordnance proving ground at Annapolis, Md., the piece used being a six-inch gun kept for experimental purposes.

Eight rounds were fired successfully, but at the ninth round the shell, loaded with two and a half pounds of the new explosive, burst in the bore of the gun with terrific violence, breaking the gun into three principal pieces, which were thrown to a distance of nearly fifty feet. Although the gun was not of service type, having been built before the high-power guns were introduced, and being used only for experimental purposes, the nature of the fractures, which showed the metal to be of excellent quality, furnished a striking evidence of the tremendous power of the explosive which could destroy this gun with such apparent ease.

U. S. Letters Patent 393,634, November 27, 1888, have been granted Arthur Favier, of Paris, France, for a new explosive and method of making the same, according to the following claims :

1. As a new article of manufacture, an explosive consisting of a highly compressed intermixture of a nitrate and a hydrocarbon, as hereinbefore set forth.

2. The method of producing the hereinbefore described explosive, consisting in intimately mixing together a pulverized nitrate, such as specified, and a water-proof hydrocarbon fusible at a low temperature, and then agglomerating said mixture under high pressure, substantially as used for the purpose hereinbefore set forth.

In making his explosive, Mr. Favier takes a nitrate, such as ammonium nitrate, and a hydrocarbon, such as paraffine, places the mixture in a mold, which is heated by hot water or steam, and subjects the mass to a pressure which depends upon the density desired. If the density is to be 1.7, a pressure of about three hundred atmospheres is required. As a result of this operation he gets a mixture which is very permanent, and so insensitive to explosion that a very powerful primer of gun-cotton or a chlorate is required to explode it. For this reason he makes his explosive up with either hollow cylinders or spheres so formed that the priming charge may be placed in the center of the cartridge.

The *Boston Globe*, November 1, 1888, states that a new explosive called "Extralite," for which U. S. Letters Patent have recently been issued to Rudolph Ericsson, of New Britain, Conn., has been tested

at that place. This powder looks like corn-meal, has the odor of oil of mirbane, and may be made over a stove. A quantity of it was placed in a fire and it refused to burn; another portion was saturated with kerosene and set fire to, when about one-half of it was slowly consumed; another portion was inserted in a cartridge of dynamite and the dynamite exploded with a fuse, but the extralite failed to explode; another portion, placed on a rock, was subjected to the blow of a sledge-hammer, but it was not exploded; and it is held that it cannot be exploded in the open by any means. A two-foot hole was then driven in a rock so hard that in the judgment of the quarrymen present two pounds of powder or one pound of dynamite would have been necessary to blast it, but nine ounces of the extralite, well tamped, shattered it to fragments. It is claimed that this explosive is safe to handle and ship, and is very cheap to manufacture. The manufacture for the trade is to be begun at once at New Britain. It is also stated that the French Government last year paid one million francs for the right to use it.

In this connection see Notes, *Proc. Nav. Inst.* **13**, 579-581 and 247-248; 1887.

We have already cited* here the preliminary notice of L. Gattermann's researches upon "Nitrogen Chloride." The complete account now appears in the *Ber. d. chem. Ges.* **21**, 751-757; 1888, and it contains a detailed description of the analytical operations. When the ordinary method of production by acting on a solution of ammonium chloride with chlorine gas is pursued, the resulting substance is invariably a mixture of the various chloramides. By washing out the ammonium chloride, and treating the moist mixture directly with chlorine, the trichloramide results. About one-half a gram of this product was heated in a thin-walled tube immersed in a beaker filled with vaselin. Up to 90° no change was observed, but about 95° a violent explosion occurred. As the effects of this explosion were most marked on the support which held the beaker, Gattermann claims that it is a characteristic of this explosive that the explosion takes place in a downward direction.

The applications which have been made of nitrogen tetroxide in the preparation of explosive substances led B. Setlick, *Listy Chem.* **11**, 241-242, to determine the yield obtained by the various methods

* *Proc. Nav. Inst.* **14**, 441; 1888.

of preparation of nitrogen tetroxide which are in use, and he obtained from 60 to 70 per cent of the theoretical yield by heating lead or calcium nitrate and by reducing starch with nitric acid. He also oxidized nitrogen dioxide with air and with pure oxygen, the nitrogen tetroxide formed being led through two cooled receivers to condense the gas, and then through sulphuric acid to dissolve the remainder. With air the yield was 138.6 grams (of which 18 grams condensed); with a mixture of equal parts of air and oxygen, 129.8 grams (of which 80.3 grams condensed) out of a theoretical yield of 156.8 grams. With oxygen alone the yield was 92.8 grams (of which 74 condensed) out of a possible 102 grams.—*Chem. Centr.* 461, 1888; *Jour. Chem. Soc.* 54, 913, September, 1888.

B. F. Oettel describes in the *Chem. Zeit.* 11, 1601, a very neat lecture experiment, which is performed by placing a small heap of finely powdered potassium chlorate on a piece of filter-paper, which is supported on a tripod, and saturating the heap with a solution of phosphorus in carbon bisulphide, which is left to volatilize. So soon as the bisulphide evaporates, the mass explodes with a loud report, and gives off clouds of smoke.—*Jour. Chem. Soc.* 54, 910, September, 1888.

Among the latest devices in the way of whistles are the curious chemical toys made with picrate of potash. When the whistling rockets and fire pieces first appeared, the whistling was commonly supposed to be produced in the same way as in ordinary whistles—by the air movements produced by their rapid motion. This is, however, not so. The operation is not at all like that of an air whistle, but the production of the sound is owing to the peculiar property of picrate of potash of whistling when it is burned. This effect is heard clearly with that salt when compressed in a tube, and the sonority may be augmented by the addition of various substances. Such a composition may be formed, with no other danger than usually attends the manipulation of explosives, by triturating a mixture of 15 parts of picrate of potash and one part of Judean bitumen. It is then charged into a pasteboard tube a little less than half an inch in its interior diameter, and some two and a half inches long. The tube is closed at one end by a plug of closely tamped clay. The composition is introduced in small charges, evenly compressed, till the tube is filled to within about three-quarters of an inch

of the open end. The whistle may be wired upon the cartridge of a rocket, when it should be furnished with a cap penetrated by a quick match, which, entering the picrated composition, is also inserted into the throat of the rocket so that the two fireworks shall be inflamed at the same time. The sound of these whistles is sharp at first, and passes gradually as the tube is emptied of its contents to a grave tone. By combining the whistle with various devices of fireworks, curious effects are produced, in accordance with which expressive descriptive names have been given to the artifices.

When the picrate whistles were first exhibited at Havre, on the occasion of the *Fête Nationale*, the spectators, irritated at the strident noise they made, and mistaking its origin, exclaimed: "Down with the whistling fellows! Duck them!" The enjoyment of the festival was much enhanced when the joke was explained.—*Boston Globe*, July 8, 1888.

An explosion of oatmeal dust, through which three men were killed, one fatally injured, and several badly bruised, and by which a three-story brick building was completely wrecked, occurred December 10, 1888, at the oatmeal mill of David Oliver, on North Halstead Street, Chicago.—*Newport News*, December 11, 1888.

The *Eng. News and Contract Jour.* 19, 25; 1888, contains a very full account, which is well illustrated, of a remarkable boiler explosion.

A. Smolka, *Monatsh.* 8, 391–398, has prepared a number of "salts of picramic acid," $C_6H_2.NH_2.(NO_2)_2.OH$, with the more commonly occurring bases, either by direction of the acid on the carbonates or by metathesis, and from the study of their properties he finds that if one of these salts is slowly heated it is quietly decomposed, but if rapidly, explosions occur, especially with the sodium and lead salts.—*J. Chem. Soc.* 54, 52; 1888. The explosive nature of the picramates was pointed out by Girard.—*Compt. rend.* 36, 421, and *Watts' Dict.* 4, 406–407; 1868.

Among a large number of "derivatives of di- β -naphthylamine" which C. Ris has obtained, *Ber. d. chem. Ges.* 20, 2618–2628; 1887, is the hexanitrodi- β -naphthylamine, $C_{20}H_9N(NO_2)_6$, which, when mixed with excess of cupric oxide, decomposes with explosive violence.

The formation of "aniline salts" with inorganic acids has engaged the attention of A. Ditte, *Compt. rend.* **105**, 813-816, 1887, and, among others, he has obtained the chlorate by mixing cold concentrated solutions of sodium chlorate and aniline hydrochloride, which he finds to be very unstable and to decompose rapidly even in the dark at 0°, while at the ordinary temperature it quickly becomes black and detonates violently at about 20°.

Among other results of his investigation of the properties and constitution of dinitrosocresorcinol, $C_6HO_2(NO_2)_2CH_3$, *Ber. d. chem. Ges.* **20**, 3133-3137; 1887, Sv. Kostanecki finds that it explodes when heated in a capillary tube above 160°.

The chloro-, bromo-, hydroxy-, nitro-, and amido-derivatives of benzoquinone have long been known, but attempts to obtain carboxyl derivatives have hitherto been unsuccessful. In *J. Chem. Soc.* **53**, 428-459; 1888, J. U. Nef gives the results of his experiments, which were undertaken to fill this gap, under the title "Carboxyl-derivatives of Benzoquinone." Durene was chosen as the starting-point, owing to the special interest attaching to the production of quinonetetracarboxylic acid, $C_{10}H_4O_{10} = C_6O_2(COOH)_4$, which has the same percentage composition as croconic acid, $C_6H_2O_5$, obtained by Gmelin from the explosive bye-product of potassium manufacture, and which has recently been critically studied by Nietzki and Benckiser.*

Among the bodies which Nef has produced is dinitrodurylic acid, $C_6(NO_2)_2(CH_3)_3.COOH$, the calcium salt of this acid being violently explosive when heated on platinum foil; diamidodurylic acid, $C_6(NH_2)_2(CH_3)_3.COOH$, which furnished a silver salt which is unstable towards heat and light and explodes when heated quickly on platinum foil; dinitropyromellitic acid, $C_6(NO_2)_2(COOH)_4$, whose silver salt explodes on heating; and dihydroxypyromellitic acid, $C_6(OH)_2(COOH)_4$, which also furnished a silver salt which is explosive when quickly heated on platinum foil. If heated slowly, however, a volatile yellow substance sublimes.

O. Fischer and E. Hepp, in continuing the examination of "Paranitrosoaniline," *Ber. d. chem. Ges.* **21**, 684-686; 1888, find that when nitrosoaniline is treated with phenylhydrazine hydrochloride, a com-

* *Proc. Nav. Inst.* **12**, 192; 1886.

pound, $C_{12}H_{14}N_4O$, is obtained which crystallizes in yellow needles, and when carefully heated melts at 125° with decomposition, but which explodes when more quickly heated. Similar compounds with phenylhydrazine seem to be given by all nitroso-bases.

Among the "Orthamidoazo-compounds of Xylene and Pseudocumene" obtained by T. Lincke and H. Jaenke, *Ber. d. chem. Ges.* **21**, 540-548; 1888, is the xylene diazoimide, $C_{16}H_{17}N_5$, which melts at 77° , decomposes at 85° and detonates when quickly heated.

In studying the "Quinone-dioximes," R. Nietzki and A. L. Ginterman obtained the toluquinonedioxime in the form of needle-like crystals which explode at 220° without melting, and the 1:4-dinitrosonaphthalene in the form of a yellow non-volatile powder which explodes at 120° .—*Ber. d. chem. Ges.* **21**, 428-434; 1888.

The dinitro-orthotolidine, $[Me_2 : (NH_2)_2 : (NO_2)_2 = 3 : 3' : 4 : 4' : 5 : 5']$, in the form of shimmering, garnet-red needles which melt at 266° – 267° and explode a few degrees higher, has been obtained by A. Gerber, while investigating the "Derivatives of Orthotolidine."—*Ber. d. chem. Ges.* **21**, 746-750; 1888.

In a paper in the *Ber. d. chem. Ges.* **20**, 2027; 1887, J. U. Nef has shown that nitranilic acid salts can be readily obtained by the action of nitrites on chloranil. In discussing "The Constitution of the Anilic Acids," *Am. Chem. Jour.* **11**, 17-26; 1889, he describes a simple method for the production of sodium nitranilate and for isolating the acid from this salt. He finds that pure dry nitranilic acid, $C_6N_2O_8H_2$, may be kept for months without undergoing decomposition, but on heating it explodes without melting at a high temperature. The salts of nitranilic acid possess at ordinary temperatures an extraordinary stability. They are all explosive, especially the mercuric salt. In their entire chemical and physical behavior they show a great resemblance to the salts of the nitro-derivatives of the fatty series, which undoubtedly have the metal bound directly to carbon. They also show resemblance to the salts of fulminic, barbituric and dilituric acids.

In studying the "Action of Nitroso-bases on Phenylhydrazine," O. Fischer and L. Wacker have obtained $C_{14}H_{16}N_4O$ by acting on nitrosodimethylaniline (3 mols.) with phenylhydrazine (2 mols.).

This substance, which the authors think may be the diazobenzene-nitrosodimethylaniline, is obtained in splendid yellow needles or plates, by carefully adding water to the alcoholic solution. It melts at 103° with decomposition, and detonates when quickly heated. When the solution in chloroform is heated it decomposes with explosive violence and liberation of carbonic anhydride.

By acting on nitrosodiphenylamine in acid solution with phenylhydrazine, the benzenediazonitrosodiphenylamine, $C_{18}H_{16}N_4O$, was obtained in crystals consisting of lustrous, gold-colored plates, which became greenish when exposed to light, melted with decomposition at 112° , and detonated when quickly heated.—*Ber. d. chem. Ges.* **21**, 2609–2617; 1888.

While investigating the properties of "Vinylamine and Bromethylamine," S. Gabriel obtained hydroxyethylamine nitrate, $OH.CH_2.CH_2.NH_2.HNO_3$, by boiling bromethylamine nitrate with silver nitrate, or by evaporating vinylamine with an excess of nitric acid. The substance forms flat, colorless, hygroscopic crystals which melt at 52° – 55° and explode on further heating.—*Ber. d. chem. Ges.* **21**, 2664–2669; 1888.

Under the title of "Oxidation of Glycerol," E. Fischer and J. Tafel describe a method for the production of lead glyceroxide by the reaction of lead hydroxide on glycerol in aqueous solution, and purification with ether and alcohol. The dry product thus obtained contains small quantities of nitric acid (from the lead nitrate used for the hydroxide). It explodes when heated, and takes fire when placed in contact with chlorine or bromine.—*Ber. d. chem. Ges.* **21**, 2634–2637; 1888.

As a result of his continued "Researches on the Diazo-compounds," P. Griess, *Ber. d. chem. Ges.* **21**, 1559–1566; 1888, has obtained the paradiatriazobenzene, $C_6H_4(N \begin{smallmatrix} \diagup N \\ \diagdown N \end{smallmatrix})_2$, [1 : 4], which explodes with extreme violence when heated above its melting point; metamidotriazobenzoic acid, $COOH.C_6H_3(NH_2)N_3$, [1 : 3 : 5], which detonates when heated in the dry state; and metadiatriazobenzoic acid, $COOH.C_6H_3(N_3)_2$, [1 : 3 : 5], which, when heated, explodes with the formation of a black cloud.

In studying the "Action of Nitrous Acid on Certain Organic Bases," W. Lossen and F. Mierau have obtained dinitrosobenzenylamidine, $C_{14}H_{14}N_6O_2$, by the action on benzenylamidine in an acid solution. This substance crystallizes in leaves which are sparingly soluble in cold water or alcohol, more readily in hot water, very readily in hot alcohol, but almost insoluble in ether. It explodes when heated to 178° , and is decomposed by an excess of acid, with evolution of gas.

By adding potassium hydroxide to a hot alcoholic solution of this compound, potassium dinitrosobenzenylamidine, $C_7H_5KN_2(NO)_2$, was obtained. This body crystallizes in needles which are readily soluble in water, sparingly in alcohol, and insoluble in ether. In the dry state the salt is very explosive, but in aqueous solution it can be boiled without any decomposition taking place. An aqueous solution gives precipitates with barium chloride, lead acetate and the like, which are also explosive in the dry state.—*Ber. d. chem. Ges.* **21**, 1250–1256; 1888.

H. Alexander finds, *Chem. Centr.* 1254–1255; 1887, that the following "Hydroxylamine Platinum Bases" are all explosive: Platoso-dihydroxylamine hydrochloride, $Pt(NH_2O.NH_2OCl)_2$; platoso-dihydroxylamine hydroxide, $Pt(OH)_{2.4}NH_2O$; platino-dihydroxylamine sulphate, $PtSO_{4.4}NH_2O + H_2O$; platoso-dihydroxylamine hydrochloride platinous chloride; platoso-hydroxylamine hydrochloride, $Pt(NH_2OCl)_2$. Free hydroxylamine, acting on platinous chloride, gives rise to the compound $OH.PtCl_{4.4}NH_2O + 2H_2O$, which explodes at 140° – 150° . It is believed that by another reaction, platinum nitrogen chloride, $PtNCl$, together with a double hydroxylamine salt, was obtained.—*J. Chem. Soc.* **54**, 425–426; 1888.

We have previously noted* that T. Klobb had discovered several compounds of ammonia with metallic permanganates which exhibited marked explosive qualities. He has since continued his investigations (*Bull. Soc. Chim.* **48**, 240–244) and has obtained the luteocobaltic permanganate, $Co_2(MnO_4)_{6.12}NH_3$, which detonates when heated and explodes when struck; the luteocobaltic chloropermanganate, $(Co_{2.12}NH_3)Cl_{4.2}MnO_4$, which detonates when heated rapidly, but does not explode on percussion; and a compound of luteocobaltic permanganate, luteocobaltic chloride and potassium chloride,

* *Proc. Nav. Inst.* **13**, 424; 1887.

$(\text{Co}_2.12\text{NH}_3)\text{Cl}_2.2\text{KCl}.4\text{MnO}_4$, which behaves like the preceding salts when heated.—*J. Chem. Soc.* **54**, 230; 1888.

In a paper entitled "On Manganese Trioxide," by T. E. Thorpe and J. F. Hambly, *J. Chem. Soc.* **53**, 175–182; 1888, the authors state that the chemical changes attending the action of sulphuric acid upon dry potassium permanganate have been differently described by different observers. It would seem in the first place that the nature of the reaction is very considerably modified by the purity of the salt and the strength of the acid. Wöhler, *Annalen* **86**, 373, observed that when concentrated oil of vitriol was poured over the crystallized salt, the permanganate was decomposed with explosive violence and with the evolution of much heat and even flame, and the formation of a cloud of finely divided oxide of manganese, large quantities of oxygen being simultaneously disengaged. Hence Wöhler concluded that free permanganic acid is a gas which at the moment of its liberation is decomposed by the heat of the reaction into oxygen and manganese dioxide. It is not improbable that the phenomena thus described by Wöhler were to some extent caused by the presence of potassium chlorate or perchlorate in the permanganate, for the authors find that pure dry potassium permanganate dissolves readily and quietly in the concentrated acid without any very extraordinary rise in temperature. If concentrated sulphuric acid is used, a clear sage-green solution will be obtained. If the monohydrated acid, $\text{H}_2\text{SO}_4.\text{H}_2\text{O}$, is employed, the color of the solution is dark brown, and it is seen to contain a number of oily drops which gradually sink, forming a dark reddish-brown liquid, which remains fluid at -20° . This substance is extremely unstable; on exposure to the air it slowly evolves oxygen, and the gaseous bubbles as they burst at the surface of the liquid form a violet-colored cloud. It is highly hygroscopic and gradually decomposes under the action of the attracted moisture. It is apparently non-volatile, it may be heated under reduced pressure to about 60° or 65° without the slightest evolution of vapor. At higher temperatures it is decomposed with a sudden and violent explosion into oxygen and manganese dioxide. The rapidity of the decomposition is probably due to the action of the separated manganese oxide, since Thenard has shown that a minute quantity of this substance, when added to the liquid, instantly resolves it, even in the cold, into these products. Silver oxide acts in the same way. It sets fire to paper, and explodes with hydrogen sulphide and the vapors of alcohol and

ether. The composition of this body was found by Aschoff, *Pogg. Ann.* **3**, 217, to be Mn_2O_7 , manganese heptoxide.

H. Debray and A. Joly state, regarding the "Ruthenium Oxides," that when ruthenium is heated in oxygen at a temperature above the melting point of silver, a portion is converted into peroxide, which is formed at a temperature of about 1000° and decomposes with explosion when cooled to 108° , but can be isolated by rapid cooling. This body affords another instance of a body which is decomposed by heat and yet is formed at a high temperature.—*Comptes rend.* **106**, 100–106; 1888.

In an article on the "Chemical Action of Light on an Explosive Mixture of Chlorine and Hydrogen," *Ann. Phys. Chem.* **32**, [2], 384–428; 1887, E. Pringsheim discusses the phenomena observed by Bunsen and Roscoe, and the theory which they offer to account for them, to which he takes exceptions while he offers a new theory of his own.

T. Bayley states in the *J. Soc. Chem. Ind.* **6**, 499–500; 1887, that when an assay of nitre in sulphuric acid is made in the nitrometer, an error is caused by the absorption of nitric oxide when the acid contains iron. Nitric oxide, shaken with mercury and pure sulphuric acid, suffers no absorption, nor does mercury pass into solution in the acid unless the acid contains a small quantity of iron. On copiously diluting the acid by the addition of air-free water, and subsequently adding a solution of a ferricyanide to the cooled acid liquid, the blue reaction is readily obtained. The mercury seems to take no part in the reduction of the ferric salt, since the results can be equally well obtained if pure nitric oxide is passed through a set of Geissler bulbs charged with sulphuric acid containing ferric sulphate. The sulphuric acid in this case, as in the nitrometer, assumes a purple tint, which is characteristic of the reaction when it takes place in the acid, but not in the aqueous solution.—*J. Chem. Soc.* **54**, 388, April 1888.

Charles E. Munroe contributes to *The Chautauquan* **9**, 203–205; January, 1889, an article upon the "Effect of Explosives on Civilization," which is one of a series of articles on civilization and the causes and forces which have affected it, that have been prepared for a course of study in the C. L. S. C.

Through the courtesy of Mr. Wolcott C. Foster we have received a copy of a pamphlet of 24 pages, entitled "Explosives and their Composition,"* which contains his contributions on this subject that were printed in the *Engineering News*, June 30 and July 7, 1888. The arrangement is an alphabetical one, and the work is a handy and useful one for reference.

* No. 6, Engineering News Technical Library, New York, 1888.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH,

APRIL, 1889.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XX.

From the Annual Report of the Chief of Engineers, U. S. A., page 353, part 1, 1888, we learn that a series of experiments was made at Willets Point by Major King, to ascertain the form and dimensions of the craters produced by different charges of explosives fired at various depths below the surface of the water.

These experiments were in continuation of some investigations made by him twenty-three years ago, when the first recorded attempt was made to measure the force of submarine explosives.

The apparatus consisted of a wooden frame 15 feet by 18 feet square, with a thin iron ring just below the center; this ring being held in position by 16 radial wires, making angles of $22\frac{1}{2}$ degrees with each other, and having their outer ends attached to the wooden frame. Upon each wire was placed a small sliding block of hard wood 2 inches in diameter at the end towards the ring and much smaller at the outer end, the length of the blocks being 4 inches and their density about the same as that of water. A small piece of rubber tubing was placed on the wire outside each block, the object being to record the distance to which the blocks were forced outward by the explosion of the charge, which was placed in the center of the ring.

*As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address *Torpedo Station, Newport, R. I.*

The charges were inclosed in paper cartridges coated with paraffine, and were exploded with platinum fuzes containing only a little granulated gun-cotton instead of the usual priming of mercuric fulminate. The charge was generally of musket powder, only a few of dynamite having been tried.

The frame containing the ring and charge was lowered vertically into the water to the desired depth, and after firing, the charge was raised and the distance to which the sliding blocks were forced back was carefully measured and plotted. In a few cases the water appears to have leaked into the charge and somewhat reduced all the indications of that round; but, on the other hand, as nothing could have caused any excess in the result, it is safe to assume that the maximum set of indications for a given charge were very nearly correct.

Although but few experiments were made, the following conclusions were thought to be warranted:

When a charge of either gunpowder or dynamite is fired under water, a large volume of water is displaced, forming a crater or cavity, spheroidal in general shape and varying in size according to the weight, nature of charge and depth in the water.

There appears to be a strong tendency to retain the spheroidal form, even when the depth below the surface of the water is considerably less than the line of least resistance that would give a "common mine crater" in ordinary earth with the same charge.

Charges exploded near the surface give larger craters and greater depressions below the center of the charge than those fired at greater depths.

While the surface of the cavity formed by the explosion is generally quite regular in form, there are frequent exceptions to this rule, which indicate that for some reason the expanding gas sometimes sends out small jets to a considerable distance beyond the general surface of the cavity. These jets are sometimes downward, but oftener in an upward direction, as would be expected.

By standing on a wharf nearly over the smaller charges when they were fired, it was noticed that the inflamed gas formed a well-defined ball of fire, and by means of photography some tolerably successful efforts have been made to catch a view of what takes place at the very instant of explosion.

The action of dynamite in forming a crater seems to be quite similar to that of musket powder, though, of course, a much smaller charge produces an equal cavity.

A few experiments were made with paper disks secured to a large iron ring, which was used in the same way as the crater-gauge already described for getting the form and size of the cavity formed by the explosion of small charges of powder and other explosives under water, but no satisfactory results have been obtained, as the paper manifested a disposition to tear out radially in such a way as to make it uncertain how much of the effect was due directly to the explosion and how much to the action of the water.

The report is illustrated with drawings and charts.

Experiments were made at Fort Lafayette, January 19, 1889, to test the new pneumatic dynamite gun. Two rounds were fired, one of which contained 300 pounds of explosive gelatine and 200 pounds of dynamite, but, according to the *Providence Journal* of January 20, 1889, both fell from 240 to 300 yards away from the target. The experiments were resumed January 26, eight rounds being fired at an imaginary rectangular target, 150 x 50 feet, placed at a distance of one mile. The gun was a 15-inch one, but the projectiles were sub-caliber, battened with wood and rubber so as to fit the bore. One of the shells contained 201 pounds of explosive gelatine and dynamite, the latter being a small proportion; the rest contained 175 pounds of explosives each, of which fifty per cent was dynamite. Four of the eight shells missed the target, one of which broke up in the air shortly after leaving the gun, while another apparently failed to explode until it had touched bottom.—(*N. Y. Herald*, January 27, 1889.)

The report of the Naval Board on the trial of this gun appears in the *Army and Navy Journal* 26, 547-548; 1889, together with the endorsement of the Secretary of the Navy. Twenty-four rounds were fired January 19, 26 and 31, part of the shells being loaded with explosives and part with sand, the object being to demonstrate the capacity of the gun to throw 200 pounds of high explosive between the limits of at least a mile and 200 yards, grouping 50 per cent of the shots of each series in a target 150 feet long by 50 feet wide. Through some error, the dynamite provided was of less density than had been specified when the sub-caliber projectiles were designed, and they were found to hold but about 170 pounds of the explosive. However, in firing these same projectiles for range from the same 15-inch gun, one containing 220 pounds of sand was thrown to a distance of 1.75 miles; a second containing over 200 pounds of explosive gelatine was thrown 1.19 miles, and a full-caliber projectile containing 500 pounds of sand was thrown to within 50 feet of one mile.

As regards the accuracy of fire, the Board reports that from the experiments it appears "that projectiles either carrying or capable of carrying 200 pounds of high explosive were thrown to distances varying from $1\frac{3}{4}$ miles to 90 yards, and that, at the ranges selected for grouping, viz. 2100 yards, 1700 yards and 360 yards, not less than one-half of the projectiles fired fell in the same standard target with the trial shot."

In the same number of the *Army and Navy Journal*, 560-561, is an abstract from the *Congressional Record* of a memorandum inserted by the Hon. Eugene Hale, on the U. S. S. *Vesuvius*, in which, after giving an historical account of the vessel and her armament, and drawing a comparison between her and foreign torpedo-boats as regards size, speed and the like, he says: "With regard to the relative effective power of these vessels as compared with the *Vesuvius*, it is necessary to revert to the comparison heretofore made between the effective zones of locomotive and aerial torpedoes respectively.

"All of the European torpedo-vessels being armed with locomotive torpedoes, it follows that their effective zones must be limited by the sure striking range of those missiles, which has been demonstrated to be about 600 feet in still water. What they would do in a heavy sea is still entirely a matter of conjecture, whereas the effective range of the aerial torpedoes of the *Vesuvius* has been demonstrated by official trials in the harbor of New York to be more than one nautical mile, and effective shots have been made up to 9000 feet, or a mile and a half. In short, so far as range and accuracy are concerned, there can be no common ground of comparison between torpedoes thrown through the air by a constantly controllable force, and torpedoes launched in the water to make the best of their way without further control or guidance.

"The following comparative statement shows more clearly the relative powers of these different types:

"*Vesuvius*.—Number of torpedoes, 30; maximum weight of each, 500 pounds of explosive; effective range, 6000 feet; rapidity of fire, three shots in two minutes.

"*Iljin*.—Number of torpedoes, 21; maximum weight of each, 180 pounds of explosive; effective range, 600 feet; rapidity, estimated once, in six minutes for each tube.

"*Tripoli*.—Number of torpedoes, 20. Other conditions as above.

"*Destructor*.—Number of torpedoes, 15. Other conditions as above.

“ Sharpshooter.—Number of torpedoes, 20. Other conditions as above.

“ Rattlesnake.—Number of torpedoes, 16. Other conditions as above.

“ Bombe.—Number of torpedoes, 10. Other conditions as above.”

The *Newport News* of April 4, 1889, states that on April 2 a preliminary trial of the pneumatic guns of the *Vesuvius* was made, in accordance with the agreement with the Government that before they are accepted they must have been fired five times in ten minutes, and that at this trial ten blank shots were fired in eight minutes. Starting with her three guns loaded as for battle, the trial proved that the *Vesuvius* could fire eighteen shells, each containing 500 pounds of explosive, in six minutes, or during the time which it would take her to steam $2\frac{1}{4}$ miles.

In addition, the results of forty blank shots demonstrated that the valve mechanism is now so perfected as to control the final air pressure, when the pressure in the reservoir is 1000 pounds, with great nicety.

In the same journal of April 26, 1889, it is stated that on April 24, during a preliminary trial on board the *Vesuvius* to demonstrate that a two-hundred pound shell could be thrown to all ranges inside of two miles and at the rate of one shot in two minutes, an accident occurred which will delay the preparing of the vessel for sea.

Three dummy shells were successfully fired, the range being a little less than one mile. A fourth shell was then inserted which was different from the first three, as it was a ten-inch sub-caliber cast-iron one weighing 500 pounds. It was placed in the middle of the gun, and when the gun was fired the shell went to pieces in the bore. As a result, the breech of the gun was badly wrecked and considerable damage was done to the mechanism, but nobody was injured.

U. S. Letters Patent No. 397052, of January 29, 1889, have been granted Stephen H. Emmens for a “gun and projectile for throwing high explosives,” in which gunpowder guns are utilized as propelling agents, by making the projectile, which is charged with high explosives, thimble-shaped, so that it may be slipped over the chase.

We are in receipt of a reprint from the *Congressional Record* of February 8, 1889, containing the remarks of the Hon. Levi Maish

in offering an amendment to the Army Appropriation Bill, which appropriates \$15,000 for testing the plan proposed by Stephen H. Emmens for converting existing ordnance of the War Department into steel-lined torpedo howitzers for throwing high explosives, and to which Dr. Emmens' memorial is attached.

From this it appears that he proposed to convert the M. L. 15-inch Rodmans into B. L. torpedo howitzers by boring through the existing breech and inserting a short lining tube of steel, which is fitted internally with an interrupted screw for the reception of a movable breech-plug, the construction of which constitutes the main feature of the converted gun. A central cylindrical hole extends through the plug, and other cylindrical chambers of larger diameter extend from the front of the plug rearwardly into its substance. These chambers contain the gunpowder forming the propelling charge, and a starting charge is placed in the central cavity, which is closed in the rear by a subsidiary breech-block carrying a firing-pin or other suitable ignition device.

The torpedo to be fired from the gun is an elongated shell charged with high explosive, and having its base extended backward in the form of a stud which fits in the central cavity of the main breech-plug. Hence, when the starting charge is exploded, a relatively weak impulse is communicated to the torpedo, which commences to move forward at a moderate rate of speed, and then, immediately the stud leaves the central tube, the heated gas inflames the main portion of the charge in the surrounding chambers, and these burn from the front backwards, keeping up an evolution of gas which urges the projectile forward throughout the whole length of the gun.

By this device the shock of firing is reduced to a minimum, and a comparatively uniform pressure is maintained until the shot leaves the gun. It will also be obvious that by suitably adjusting the air-spacing of the several sections of the charge, and by properly selecting the character of the powder employed, the pressure may be fixed at 10 tons per square inch or any other possible amount; while owing to the front ignition of the main sections, the whole of the powder may be utilized instead of being blown out in a partially consumed state, as is almost invariably the case in guns of ordinary types.

He proposes to use emmensite in his shell, and expects to be able with 115 pounds of powder to throw from these converted guns a shell containing 534 pounds of the explosive to a distance of three miles.

The *New York World* of January 22, 1889, devotes considerable space to the description of a method of defense of New York harbor in which petroleum is to be the active agent. It is proposed to lay a system of pipes along the shores of the Hook and Long Island which are connected with large reservoirs of petroleum and lead under water to the main ship-channels. The mouths of these pipes are to be closed by valves which are held in place by the pressure of the water, but which can be forced open by pressure applied to the fluid inside. The petroleum will thus be discharged into the water, where it will rise to the surface and be ignited by fire-balls, etc., which are thrown from the shore. It is hoped that the smoke produced will be sufficient to make navigation impossible, so that the vessels of the hostile fleet will destroy one another by collision, or that it will be dense enough to prevent them from using their guns, while they may remain sufficiently visible to serve as a target.

On November 21, 1888, an explosion occurred on board the petroleum-laden "ketch" *United* while lying in Bathurst Basin, Bristol Docks, England, which blew up the docks, killed three of the crew, threw the fourth into the water (whence he was recovered seriously injured), injured a policeman on the quay, shattered the glass in the windows about for a radius of ninety yards, and liberated and ignited the petroleum spirit, which destroyed the vessel and did further damage to the dock and the buildings about it.

The circumstances attending the explosion were thoroughly investigated by Col. V. D. Majendie, H. M. Chief-Inspector of Explosives, and made the subject of a special report to the Home Department. He found that the cargo consisted wholly of the petroleum designated in the trade as "Pratt's deodorized naphtha," and commonly known as "benzoline," it being an exceedingly light, volatile liquid, having a specific gravity of .7034, and giving off inflammable vapors abundantly even at the freezing point of water; that there were 310 barrels of 40 gallons each in the hold, which was separated from the fore-castle and cabin by 1½-inch thick, close-joined (tongued and grooved) bulkheads without any openings whatever, though they were not air-tight; and that the natural leakage from the cargo during the time it had been in the hold was sufficient to have rendered the atmosphere of the vessel between decks thoroughly inflammable.

He found that there had been no attempt to conceal the explosive and inflammable nature of the cargo, but that on the contrary

everybody connected with the handling and transportation had been repeatedly warned not to have any fires, lights or matches about the vessel, and that a policeman had been stationed on the quay to see that the prohibition was enforced; yet in spite of this, Col. Majendie was led to the conclusion that the explosion was caused by some one's striking a match in the cabin, by which the inflammable vapor, which had reached that portion of the vessel, was ignited and immediately carried the flame forward to the hold. This conclusion is strengthened by the fact that the master of the vessel exhibited considerable impatience at the restrictions placed upon him, and intimated that an unnecessary amount of fuss was being made about the cargo, as he had been used to carry dynamite and never had had so much fuss made about that, which showed that he failed to appreciate the fundamental distinction between a cargo of dynamite and one of petroleum spirit, viz. that in the case of the former an explosion from fire cannot take place unless fire be brought to the dynamite, while in the case of the latter the dangerous vapors will travel to a fire at considerable distances and even through intervening bulkheads; so that, while one might have had fires and lights in the cabin without serious danger when dynamite was on board, yet with petroleum spirit in the cargo it was almost certain to lead to disaster.

It was further found that the vessel itself was wholly unsuited for the use to which it had been put; for vessels in which the cargo in the hold consists wholly or partially of petroleum spirits or similar highly volatile and inflammable liquids, should have all cabins and galleys on deck, while the cargo should be battened down, and no one should be permitted below during the voyage.

In the course of this investigation several interesting experiments were made. Thus Dr. Dupré showed that one volume of the liquid naphtha, such as was on board the *United*, would render 16,000 volumes of air *inflammable* (one cubic inch to 9.2 cubic feet of air), or 5000 volumes of air *strongly explosive*, while it would render 3000 volumes of air combustible but only slightly explosive. He found, too, that one volume of the liquid yielded 141 volumes of vapor at the ordinary temperature, so that one volume of the vapor would render 113 volumes of air inflammable and 35 volumes of air strongly explosive.

From the experience at the largest petroleum stores in London, it was estimated that the normal rate of evaporation of such petroleum spirits when in sound barrels and good condition was about 16 per

cent per annum, which for the quantity on board the United would give a normal daily rate of six gallons, and this would be sufficient to render 5000 cubic feet of air explosive.

To determine whether or not a mixture of petroleum vapor and air may be ignited by means of an ordinary spark, Dr. Dupré and Colonel Majendie repeatedly placed the incandescent end of a freshly extinguished wooden match in a jar containing the mixture, without firing it. When a flaming match was introduced, ignition or explosion invariably ensued.

The same results followed when incandescent match-ends were introduced into a wooden box in which the evaporation of petroleum spirit had been established, while on all occasions the flaming match produced ignition.

Showers of sparks from a flint and steel were repeatedly produced inside a box charged as last described without causing ignition, while pieces of red-hot coal were held over a small quantity of the petroleum spirit which had been spilled on a wooden floor, and in one or two instances particles fell on the liquid also without causing ignition.

A platinum wire was introduced into a jar of the mixture and heated by a current. So long as the wire was at a low or red heat no action ensued, but when the wire approached a white heat explosion invariably followed.

Mr. Boverton Redwood has also made some experiments with mixtures of air and benzoline vapor which are interesting in this connection. He introduced some of the Japanese parlor fireworks (known as "scintilletes") while they were emitting brilliant sparks but after they had ceased to flame, into a jar of this mixture, and the latter was not ignited, but it did ignite immediately on the application of a flame. Then he introduced a "fixed star" vesuvian (as used by smokers) immediately after it had ceased to flame, and while combustion was proceeding from the point to the head, into a similar jar of the vapor, and the incandescent mass remained in the vapor until it had cooled, but without igniting the vapor. Then he attached two fuzees or vesuvians (of the non-flaming description) to a wire, so that the tip of one was in contact with the head of another. He ignited the latter, and as soon as it had ceased to flame, he plunged them into a jar of the vapor, where they remained, while the combustion proceeded from the tip to the base of the first without effect; but immediately that the combustion extended from the base of the one to the tip of the other and a *flame* was produced, the contents of

the jar were inflamed and exploded. Finally he allowed a stream of sparks from the fireworks known as "Golden Rains" to fall into a jar of the vapor, and again no ignition ensued.

These experiments may be performed with a mixture of one volume of the liquid to 6000 volumes of air, this being found to be the most explosive mixture.

As is customary in these admirable reports by Colonel Majendie, he gives here a résumé of the more important instances of similar accidents which are on record, and it is interesting to note how comparatively slight the damage done by the oil burning upon the water is and how easily its spread is arrested. Thus in the case of the *United*, though another vessel which was not more than 40 feet to windward from her was surrounded by flames from the burning spirit, yet she escaped unharmed, and the flow of the spirit was arrested by means of booms.

Through the courtesy of M. P. F. Chalon we have received a copy of a trade pamphlet of some 40 pages, entitled "The New Explosive, Bellite," which contains the reports of tests of this explosive made at different times by the Association of Chemists at Stockholm, Lieutenant C. O. Nordahl, Professor P. T. Clève, P. F. Chalon and A. W. Cronquist, together with various press notices of its use, all of which tend to show the great efficiency, permanency and safety of the explosive.

Among the more striking of the experiments described is that of heating the explosive in a covered platinum crucible by means of a blast-lamp, when the explosive burnt away with flame, but without explosion; and that of igniting a portion which was placed in a mixture of sulphur and potassium chlorate, where it also burnt without explosion. Other experiments given in the pamphlet have already been cited in these Notes.*

Chalon states in his report that bellite consists of ammonium nitrate five parts and dinitrobenzene one part; that it is offered both in the form of powder and of compressed cartridges, is of a yellowish color, almost dry to the touch, and resembles ammonium nitrate in smell and taste.

On February 5, 1889, an experimental exhibition of the properties of bellite was made at Wangey Hall Farm, Chadwell Heath, Eng-

* Proc. Nav. Inst. **13**, 247-248 and 579-581; 1887.

land, in the presence of a large number of visitors, an account of which is given in the *Engineer* 77, 116-117; 1889.

The inventor claims for bellite the following advantages: 1, That bellite is one of the most powerful explosives known; 2, that it is more powerful than either gun-cotton, dynamite, or gunpowder; 3, that it possesses qualities of safety entirely foreign to explosive substances generally; 4, that bellite presents no danger whatever in manufacture; 5, that it cannot be made to explode by friction; 6, that it cannot be made to explode by shock or by pressure; 7, that it cannot be made to explode by electricity or by lightning; 8, that it cannot be made to explode by fire; 9, that it cannot be made to explode by any means except by the aid of a detonating cap, and is therefore absolutely safe; 10, that on being exploded, no noxious gases are given off, as is the case with dynamite and all nitroglycerine compounds; 11, that bellite made expressly for coal or rock blasting does not shatter like dynamite, but forces the coal or rock out in larger blocks, making but a very small percentage of dust; 12, that it does not undergo any chemical change from time nor from atmospheric influences, always retaining its non-explosive character until the fulminating cap is applied to it; 13, that it can be used in shells that would prove of a terribly destructive character. Dynamite cannot be so applied, as the concussion produced by ignition of the gun-charge would be liable to explode the shell and burst the gun. Bellite shells, however, may be fired without any such risk, thus solving the problem of firing high explosives from ordinary guns, hitherto an impossibility. 14, That bellite can be manufactured in tropical climates, which is not possible with dynamite; 15, that it can be transported by land or sea with perfect safety, being carried in Sweden as ordinary merchandise; 16, that it requires no thawing in the coldest weather, like dynamite, consequently much time is saved; 17, that it can be profitably sold at a lower price than dynamite or any other nitroglycerine compound. At present there are about 60 factories in Europe making dynamite and similar compositions, producing annually 40,000,000 pounds.

1. The programme was commenced by firing a charge of $1\frac{1}{2}$ pounds of bellite in a can under water. As the bellite was enclosed in a water-tight case, there was nothing in this test to notice.

2. A bellite 4-ounce charge—which somewhat resembles a stick of sulphur with a perforation at one end—was broken in two, the solid end being thrown into a coal fire, where it melted and burnt without

attracting notice, and the perforated end being exploded by means of a fuze and detonator, on $\frac{3}{8}$ -inch boiler plate, which it bulged. This illustrated the fact that bellite will not explode by ordinary combustion, while its action on ignition by a detonator is very powerful.

3. An iron 120-pound weight was dropped from a height of about 16 feet on five charges of bellite laid on an iron plate. The first blow not being quite end on, this was repeated, when the bellite was crushed to powder without explosion.

4. The crushed bellite thus produced was then placed in a tin which held 5 ounces, and fired by a detonator in contact with an old S. E. R. iron steel-faced rail, which was fractured. This illustrated the power of bellite to resist explosion under a blow when in contact with iron.

5. In a hole 3 feet deep was buried 1 pound of blasting powder mixed up with naked bellite cartridges or charges, and the powder fired by a plain powder fuze, when the bellite was thrown about and blackened, and the surface burnt in places, but apparently none of it was exploded.

6. A charge of bellite was fired like a bullet from a small-arm, "No. 8," $\frac{1}{16}$ -inch bore, against a $\frac{3}{8}$ -inch boiler plate. Bellite was found in small pieces adhering to the face of the plate unexploded.

7. The propelling power of bellite was next shown by the following experiment: A 32-pound shot was discharged from a short mortar, first by a charge of $\frac{1}{2}$ pound of powder—Curtis and Harvey's—and then by $\frac{1}{4}$ pound of bellite. In the former case the shot fell at 40½ yards from the mortar, and in the second at about 95 yards, illustrating the great superiority of bellite over the double weight of powder fired under these conditions for propulsion.

8. Charges of dynamite and bellite, 4 ounces each, were placed on similar $\frac{3}{8}$ -inch boiler plates, and after being covered with clay, which was pressed over them, were fired. The effects were very nearly identical in this case. It is, however, said that experience has shown that the injury effected by dynamite is generally more local, and that of bellite more distributed.

9. The fuzes of mines in the earth charged with gunpowder and bellite were now ignited. The powder exploded, but the bellite fuzes failed.

10. A charge of 8 pounds (10s. worth) of bellite which had been buried 3 feet beneath a length of 60 feet of railway line laid in chairs fixed in cross sleepers with fishes, etc., complete, was now exploded by

the usual detonating fuze. The entire structure for many feet was lifted high in the air, the rails being both broken through in one place, while one rail was bent at some feet distance from the point of fracture, the fishes of the other rail being broken through at a nearly equal distance. The sleepers were torn and split and one chair broken. A crater was opened in the ground about 12 feet in diameter.

Some of its properties were necessarily not tested ; for example, its freedom from all flame and the harmless character claimed for its products of combustion. Then, again, its power to explode when in contact with water was not exhibited. It may be noticed, in addition to what has been mentioned above with regard to the thirteenth claim put forward by the inventor, namely, its suitability for bursting charges of gun shells, that a delay-action arrangement has been devised to enable steel shells to perforate armor before explosion takes place.

In a lecture on "Blasting Gelatine and Bellite," given before the Philosophical Society of Kilmarnock by J. Guthrie Kerr, the lecturer stated that blasting gelatine (nitroglycerine 97 per cent and gun-cotton 3 per cent) was 50 per cent better in explosive effect than dynamite. It is entirely unaffected by water, and cartridges which have been immersed for seven years have at the end of that time developed their full power when detonated. Gelatine dynamite (blasting gelatin 80 per cent, wood-meal and saltpeter 20 per cent) is largely used in fiery mines in England as the charge in Settle's application of Abel's water shell.* This consists of a rubber bag filled with water, with the gelatine-dynamite cartridge held in place in the middle by tin supports. This cartridge requires large bore-holes, which is a disadvantage and expense, and hence bellite has been proposed for use in these mines, it being claimed to be 30 per cent stronger than dynamite, absolutely safe for transport, and flameless. As regards this last claim there seems to be a want of evidence as to the effects of other than comparatively small charges under favorable conditions. In the meantime the claim could not be considered as made good, whatever the promise might be. Compared with blasting gelatine, it is inferior so far as concerns the power of withstanding water, as might be inferred from the presence of such a large proportion of nitrate of ammonia. If as a protection against water it be

* Proc. Nav. Inst. 14, 766 ; 1888.

covered with a water-proof mixture, it becomes less adapted for filling holes.—(*Jour. Soc. Chem. Ind.* 8, 213; 1889.)

In view of the attention which the nitro substitution compounds are now receiving, U.S. Letters Patent No. 157143, dated November 24, 1874, which were granted C. W. Volney for "Volney's Powder," may prove of interest.

His invention consists in mixing nitrated naphthaline with an oxidizing agent, the nitrated naphthaline being obtained by the action of nitric acid upon naphthaline. The result of this treatment is a yellow substance consisting of mono, di, tri, or tetra nitro-naphthaline, in which one or more atoms of nitrogen-tetroxide are substituted for the corresponding number of hydrogen atoms. Strong nitric acid and high temperature will produce the higher nitrated bodies, as di and trinitro-naphthaline. From weaker acid and lower temperatures mono and dinitro-naphthaline will result.

All these different nitro bodies will form useful explosive compounds when mixed with equivalent quantities of an oxidizing agent, which can supply sufficient oxygen to oxidize the surplus of carbon, more or less oxygen being furnished by the nitrogen-tetroxide of the nitro-naphthalines; and it follows that the higher the naphthaline has been nitrated the less of the oxidizing agent will be needed, but the greater will be the breaking power of the explosive compound.

This quality he makes use of to prepare powders of different strength in the following manner: To prepare an explosive of great breaking power for the filling of torpedoes, submarine blasting, blasting of hard rock, etc., he treats naphthaline with strong nitro-sulphuric acid (two parts sulphuric acid of 1.84 specific gravity and one part nitric acid of 1.5 specific gravity) at a temperature of 212° Fahrenheit. One hundred pounds of naphthaline require four hundred pounds of this acid. The reaction is finished in one hour. All the naphthaline is then converted into a yellow crystalline mass, which is thoroughly washed with water, dried, and pulverized. It consists mainly of di and trinitro-naphthaline, and he calls it, for this purpose, "Nitrated Naphthaline No. I."

A good blasting powder of great breaking power is obtained by thoroughly mixing the following substances: 2.18 pounds nitrated naphthaline No. I, 0.19 pound saltpeter, 0.16 pound sulphur.

To prepare an explosive of less breaking power, which is therefore better adapted for military purposes, blasting in soft and fissured

rock, as gypsum, limestone, etc., he incorporates one hundred pounds of naphthaline into four hundred pounds of nitric acid of 1.40 specific gravity, leaving these substances in contact for four or five days. The naphthaline is converted into a brown crystalline mass which is washed with water, dried, and pulverized. It consists mainly of mono-nitro-naphthaline. He calls it, for this purpose, "Nitrated Naphthaline No. II."

The required explosive compound is formed by mixing thoroughly 1 pound nitrated naphthaline No. II, 3.30 pounds saltpeter, 0.51 pound sulphur.

All these substances can be pulverized, mixed, and treated in the same manner as the substances used for and in the manufacture of common blasting or gunpowder. Instead of saltpeter any other nitrate, or any chlorate, as sodium nitrate, potassium chlorate, may be used.

The powders prepared in this manner are of a yellow color. Friction or concussion will not ignite or explode them. In unconfined packages, if brought in contact with fire they will ignite and burn, but not explode. Before commencing thus to ignite, the powder will first partially melt and then burn.

To effect an explosion when desired, caps with mercury fulminate, or a small addition of gun-cotton or nitroglycerine, must be used. The heat and concussion instantaneously developed by these bodies in their explosions will explode these powders. The same may be used with or without confinement, but the powder No. II should not be used without confinement or tamping.

Their indifference to friction, concussion, and heat under all circumstances render their handling and transportation safe. Their effective labor is very great.

He claims as his invention the explosive compound composed of nitrated naphthaline, substantially as described, and an oxidizing agent prepared in the manner and substantially in the proportions and for the purposes set forth.

U. S. Letters Patent No. 397095, January 29, 1889, have been issued to Rudolf Sjöberg for a blasting compound, the chief ingredients of which are an ammoniacal salt, a hydrocarbon, and chlorate of potash, the ammoniacal salt to be either the nitrate or oxalate. If the nitrate is used, a part of it is replaced with carbonate of ammonia. The hydrocarbon used is non-nitrated, and may be partly in the liquid

and partly in the solid form, or wholly solid. For the liquid hydrocarbon he preferably uses the so-called "Astral Oil," and as the solid hydrocarbon naphthalene, though other similar hydrocarbons, such as paraffine, may be used, observing only that the liquid hydrocarbon should be of such a kind as does not easily evaporate; hence benzene is not suitable.

The preparation or manufacture is as follows: The salts to be used should be finely pulverized, and must be well dried so as to be free from hygroscopic moisture. The solid hydrocarbon is first melted, and may be used alone, but is preferably mixed with the liquid hydrocarbon, being heated sufficiently for the purpose. This mixture is then divided in two unequal parts; one part, say about two-thirds, and the other part one-third of the whole. After this the ammoniacal salt, either in the form of nitrate or nitrate and carbonate, or in place of these the oxalate, is added to the larger part of the hydrocarbon mixture and carefully mixed with it by stirring. Chlorate of potash is similarly mixed by stirring with the smaller part of the hydrocarbon. The mixtures thus obtained are then mixed with each other, after which the blasting compound is ready.

The following is an example of the proper proportions for the ingredients: Fifty parts nitrate of ammonia, five parts carbonate of ammonia, ten parts liquid hydrocarbon, five parts solid hydrocarbon, and thirty parts chlorate of potash; or fifty parts oxalate of ammonia, ten parts liquid hydrocarbon, five parts solid hydrocarbon, and thirty-five parts chlorate of potash.

The proportions of the ingredients may, of course, be varied according to the purpose for which the compound is intended to be used, whether for blasting or for artillery service, etc. The following will serve as an example for such variations: Thirty to sixty parts nitrate of ammonia, one to five parts carbonate of ammonia, five to twenty parts liquid hydrocarbon, one to ten parts solid hydrocarbon, and five to thirty-five parts chlorate of potash.

It is claimed that this blasting compound cannot be exploded except within rigid enclosures, such as shells or other projectiles, or a hole bored in a rock, and then only by the use of a so-called "dynamite percussion-cap." In bored holes the percussion-cap is exploded by a fuze; but the blasting compound cannot be exploded by a fuze alone, the latter only being used to explode the percussion-cap; nor can it be exploded by concussion, such as blows against iron or stone. It will not freeze. It cannot be exploded by ramming it in a bore-

hole, nor by the application of flame ; but it may be ignited, in which case it will burn very slowly. It may be heated up to and above 100° C. without danger of explosion. If a fuze is applied to ignite it without the use of the percussion-cap, the fuze will burn out without igniting the powder. In order to be exploded it must be placed within a rigid enclosure, as before stated ; it will not explode when placed loosely upon a rock. It will not explode under any circumstances in the open air, even if a dynamite percussion-cap is used ; nor will it explode if thrown upon a red-hot iron plate, nor in a cartridge, unless the latter be placed within a rigid enclosure out of contact with the air, as when used in bombs or other projectiles, or in a rammed bore-hole, and then only by a percussion-cap ignited by a fuze or by electricity.

The letters patent claim as new :

1. " A blasting compound consisting of oxalate of ammonia, a non-nitrated hydrocarbon, as naphthalene, and chlorate of potash, substantially as set forth.

2. " A blasting compound, consisting of oxalate of ammonia, a liquid non-volatile hydrocarbon, as astral oil, a solid hydrocarbon, as naphthalene, and chlorate of potash, substantially as hereinbefore set forth."

In *Ding. Poly. Jour.* **270**, 215-223 ; 1888, O. Guttmann says that greater attention has of late been directed to the electrical phenomena* so often observed during the process of manufacturing gunpowder, but concerning which no safe conclusions have been arrived at, owing to the absence of the evidence of reliable observers.

The most important and also the most common occurrence is the accumulation or attraction of atmospheric electricity during storms. The buildings of explosive works, as a rule, are detached and often in elevated positions. In England it is prescribed that the lightning conductor should be fixed *on to the building itself*. In other countries it is considered sufficient to attach the lightning conductor to a high staff near to the building, and we are of opinion that the buildings in question are afforded more protection. In many cases the lightning conductor has been known to favor the discharge of electricity, and it is suggested that an explosion of a powder magazine at Salonica occurred in this way.

* Proc. Nav. Inst. **12**, 181-182 and 423-424 ; 1886.

As regards the machinery in the buildings, precautions should be observed against the accumulation of atmospheric electricity as well as from other sources, more especially in the manufacture of explosives of which sulphur is a constituent. In the powder works of W. Güttler the sulphur mills are connected with the earth so as to carry off the electricity, and since this arrangement has been introduced the sulphur has never fired, it being previously a matter of constant occurrence.

In another large powder works in Germany not long since an explosion occurred in the press-house after a storm. The powder was between ebonite plates and under pressure before the commencement of the storm. When the storm had ceased, a workman released the pressure and proceeded to separate the cakes from each other. According to a statement made by him before his death, a spark 10 centimeters in length was discharged into his finger as he was in the act of lifting one of the cakes.

W. T. Reid has observed that warm air passing over nitro-cellulose generates electricity in considerable quantities. The generation of electricity has been observed in other industries during manufacturing processes, and several instances are quoted; but, according to the author, no instance has come to his knowledge which is of importance or which has caused immediate danger.

The author considers that the extensive application of rubber, ebonite, etc., to machinery used for the manufacture of explosives is somewhat hazardous. In England, for instance, the shoots of the separators and the bed-plates of the granulating mills are lined with rubber composition. This stuff has the advantage that it wears well and possesses considerable elasticity combined with great strength, etc., but under favorable conditions such a bed-plate might act as an electrophorus.

The author considers the question of the accumulation and attraction of electricity one which should receive greater attention, and observes that it should be made compulsory to connect all machinery and apparatus with the earth by properly constructed conductors.

Eng. Patent No. 1469, January 31, 1889, has been granted A. Nobel for an explosive mixture to consist preferably of charcoal, barium nitrate, and ammonium picrate, or amorphous phosphorus. The two last ingredients are added in order to counteract the slow combustion inherent to barium nitrate powders.

Otto Hehner gives a valuable paper in *Jour. Soc. Chem. Ind.* 8, 4-9; 1889, on the "Estimation of Glycerine in Soap Lyes and Crude Glycerine," in which he describes at length the direct extraction, lead oxide, bichromate and acetin methods, and shows the two latter methods, which are so unlike in principle, agreeing in results. In connection with the direct extraction method, he states that when the solution contains more than 74 per cent of glycerine, the latter is volatilized at high temperatures, "and at temperatures beyond 100°, say 110°, as prescribed and practiced in large continental dynamite works, the loss is anything the operator may like to make it."

In discussing this paper, W. F. Reid said that all scientific analytical tests such as Mr. Hehner had described were regarded as almost useless in the dynamite factory. They used such methods as far as possible, but they mainly depended on a series of practical tests. The first step was to ascertain the amount of chlorine in the glycerine. If a sample showed much chlorine it was at once rejected, chlorine being one of the greatest sources of danger in a dynamite works. The next test was to gently warm the glycerine with sulphuric acid. If it discolored the acid much, the glycerine was rejected as being likely to cause heating in the nitrating vessel. For the detection of the fixed substances they heated the glycerine in a platinum capsule. They did not take the great precautions indicated by Mr. Hehner during this evaporation, and no doubt small portions of the mixed substances passed off with the glycerine. But they did not trouble about that. If they found an appreciable residue they rejected the glycerine, not on account of the danger, but as containing impurities in themselves useless. Of course crude glycerine was not used for nitrating purposes, as it would be dangerous. They tested that body practically by distilling it in superheated steam. That was the best test of its suitability for manufacturing purposes. There might be a certain percentage of pure glycerine in a crude glycerine, but there were also complex organic bodies present which destroyed a proportion of the glycerine in distillation and thus prevented the manufacturer from getting the yield of pure glycerine which analysis indicated as being obtainable. The final test of the pure glycerine was nitration. Nitration was done in the ordinary way and with the usual acids used in the factory. The practical yield was always lower than by the refined methods described by Mr. Hehner, because of the solubility of the nitroglycerine in the acids which were used to nitrate it. They had tried to precipitate the nitroglycerine from the

acids by dilution with water, but had found it to be also to some extent soluble in the acid water, so that only a small proportion of the dissolved nitroglycerine could be recovered in that way. The best method was to freeze the solution. He was quite aware that the tests he had described could not be considered accurate quantitative methods, but they were tests which enabled manufacturers to know what results to expect in actual working, those results being always considerably below the theoretical yield of pure glycerine; roughly speaking, he would say at least 5 per cent below it.

It has been observed some time since that when mixtures of hydrogen and oxygen, in the proportion of 2 to 1, are exploded in a very long tube, an explosive residue remains unburnt even when the oxygen is in excess. This "Imperfect Combustion in Gaseous Explosions" has been studied by H. B. Dixon and H. W. Smith, and the nature of the residual gas, with varying compositions for the original mixtures, determined. The tube used was 100 m. long and 9 mm. in diameter, with a capacity of 8100 cm³. and an internal surface of 29,000 cm². With three mixtures—A, in which hydrogen was in slight excess, and B and C, in which oxygen was in excess—the following mean results were obtained:

	A.	B.	C.
Average residue,	150 cm ³ .	160 cm ³ .	220 cm ³ .
H } CO }	54.3 p. c. ...	29.5 p. c. 5.1	20.5 p. c. 5.8
O	19.4	38.1	32.7
N	26.3	27.3	41.0

Other experiments showed that the extent of the surface of vessel or tube employed does not exert any great influence on the explosion of the gases. Similar results were obtained with mixtures of carbon monoxide and oxygen. These results appear to confirm the observations of Mallard and Le Chatelier that the cooling in this method of combustion is more rapid than in ordinary combustion, and they also bear on Berthelot's theory of the mode of propagation of explosion waves.—(*Chemical News* 59, 65–66; 1889.)

The term catalysis was first applied by Berzelius, *Ann. Chim. Phys.* 37, 66, to the power shown by certain substances of causing decomposition or other chemical changes in other substances without being themselves affected.

Dulong and Thénard have shown, *Ann. Phys. Chem.* **76**, 81, that all metals and some earths can determine chemical union between oxygen and hydrogen at temperatures below the boiling point of mercury, and in the case of platinum, palladium, rhodium, and iridium, at ordinary temperatures. Faraday has shown, *Ann. Phys. Chem.* **33**, 149, that the action of platinum on oxyhydrogen gas occurs at ordinary temperatures only when the surface of the metal is perfectly clean.

Henry, *Phil. Mag.* [3] **6**, 354, and Turner, *Annalen* **2**, 210, have shown that copper and iron turnings, zinc-foil and wood-carbon have the same effect on oxyhydrogen gas, but only at temperatures not far below the boiling point of mercury; and Loew, *J. pr. Chem.* [2] **11**, 372, has shown that glass begins to act in the same way at about the same temperature.

Berthelot, *J. Chem. Soc.*, Abstr., 1022; 1882, pointed out the connection existing between catalytic action and occlusion of hydrogen, and the following paper contains an account of an extensive series of experiments directed to the further elucidation of the subject. In studying the "Catalytic Action of Metals on Oxyhydrogen Gas and the Occlusion of Hydrogen," *Ann. Phys. Chem.* **35** [2], 791-810; 1888, A. Berliner arrives at the conclusion that these catalytic actions are invariably due to the occlusion of hydrogen, which, when occluded, always seems to act in the same way as when in the nascent state, as Graham, *Phil. Mag.* [4] **32**, 503, showed conclusively in the case of palladium. The fact that when the metallic surface is not clean, catalysis still takes place at high temperatures, is attributed by the author to the partial removal of the film of impurity when the temperature is sufficiently increased; this is in accordance with Graham's observation that the largest amount of gas was occluded when the metal was first strongly heated and then allowed to cool in the gas forming the subject of experiment.

The "Decomposition of Potassium Chlorate by heat in the presence of Manganese Peroxide," which takes place with great readiness, has sometimes been referred to as due to the catalytic action of the oxide. Investigation of the phenomena by H. McLeod, *Jour. Chem. Soc.* **55**, 184-199; 1889, and by W. R. Hodgkinson and F. K. S. Lowndes, *Chem. News* **58**, 309; 1888; **59**, 63-64; 1889, of the action of various metallic oxides, shows that the process is one of considerable complexity, but is purely chemical, and that the manganese oxide is repeat-

edly oxidized and reduced with the intermediate formation of potassium manganate and permanganate.

It has long since been observed that when water is electrolyzed by means of an alternate current, the mixed gases in the voltameter sooner or later explode. De la Rive, who noticed the phenomenon, attributed it to the catalytic action of the platinum black which he saw formed on his platinum electrodes. Bertin attributed it to the polarization of the electrodes.

In studying the mechanism of electrolysis by means of alternating currents, G. Maneuvrier and J. Chappuis found these explosions a constant source of trouble, and so they carefully investigated the phenomenon with a view to its prevention. Their results, given in the *Comptes rend.* **107**, 92; 1888, under the title "Spontaneous Explosions occurring during the Electrolysis of Acidulated Water by Alternating Currents," show conclusively that the explosion of the mixed gases is brought about by the platinum electrodes becoming heated to such a point as to determine the recombination of the dissociated elements. This heating is due to three causes, all of which depend ultimately on the gradual descent of the level of the electrolyte, in the voltameter, thus having more and more of the electrodes in contact with the gases. Firstly, owing to the smaller surface of the electrodes the current density is increased; secondly, the surface resistance is increased; thirdly, the cooling action of the electrolyte is decreased. It becomes, therefore, easy to prevent the explosion by taking due precautions to guard against the heating of the electrodes.

The *Comptes rend.* **107**, 96-99; 1888, contains a paper by Mallard and Le Chatelier, "On the Method of Blasting in Fiery Mines."

The results of the researches of Berthelot and of Sarrau and Vieille enable us to determine with considerable precision the properties of the explosive substances. Up to the present, however, they have considered chiefly the mechanical effects of these bodies, passing by, as a secondary consideration, the temperature of the gases at the moment of detonation and before they have had time to cool even partially.

This temperature can be calculated by applying to the gaseous products of the reaction, the values, increasing with the temperature,

for the specific heats of the gases; such have been obtained by these authors in their former experiments.*

One can verify the accuracy of the temperatures calculated in this way by comparing them with the observations made by different experimenters, and notably those of Sarrau and Vieille on the pressures developed in closed vessels by detonating explosives.

In effect, when the temperature is high and the volume of the gas is not too small, we may calculate this pressure P by the formula

$$P = \frac{f - \Delta}{1 - a\Delta}, \quad (1)$$

which is deduced from Clausius' formula, in which

$$f = \frac{1.0333v_0 T}{273\omega} \text{ and } a = \frac{uv_0}{\omega}, \quad (2)$$

where

Δ = density of loading = $\frac{\omega}{V}$.

ω = weight of explosive in kilograms.

V = volume in liters of vessel in which detonation takes place.

P = pressure in kilos. per cm². of vessel in which detonation takes place.

T = temperature of detonation in absolute degrees.

v_0 = volume of gases produced at 0° and 76 cm.

u = a coefficient called the *covolume*.†

The authors have proved that the experiments of Sarrau and Vieille on the pressures developed by cellulose endecanitate, ammonium nitrate, and a mixture of cellulose endecanitate 60 parts and ammonium nitrate 40 parts, verify, very exactly, expression (1), and this demonstrates that the law of the covolume applies even at temperatures approaching 3000° and pressures of more than 7000 atmospheres. From the lowest of these temperatures and pressures to the most considerable it appears, at least for the gases which we encounter in the products of the detonation of explosives, *as if the gaseous molecules had an invariable volume which is the same for all, and which is very nearly equal to the one-thousandth of the gaseous volume at zero and under atmospheric pressure.*

* Comptes rend. 1882, and Annal. Mines, 1883.

† The value of this coefficient has been calculated for different gases by Sarrau from the experiment of Armagat, but the authors believe that the value should be the same, or very nearly so, for all gases, and they have taken it as equal to 0.001.

They have shown further for those explosives in which the ratio of the perfect gases to the carbon dioxide and water vapor is relatively small (such as dynamite and the mixture of gun-cotton and ammonium nitrate), that the agreement between f observed and f calculated from the temperature of combustion is very close when their own data for the specific heats of CO_2 and H_2O is used. The difference in the values is not more than three per cent.

When the perfect gases are present in considerable quantity, as in gun-cotton and picric acid, the difference reaches to ten per cent, and will be much greater if it is held that the molecular specific heat of perfect gases is constant at all temperatures. To represent the results of the experiments it is necessary to admit that the coefficient b in the formula $c = a + bt$, which was taken for perfect gases as equal to 0.0006, becomes at least 0.0013. The increase of the specific heats of the perfect gases with the temperature which is deduced from their experiments is confirmed most completely by the observations of Sarrau and Vieille on the pressures developed by explosives detonated in closed vessels.

The commission on explosives which has recently been studying the important question of blasting in fiery mines, has arrived at results which strongly confirm the preceding deductions. This commission has proved by numerous experiments that explosives, when detonated in the midst of fire-damp mixtures, cannot inflame them except when the temperature of detonation exceeds 2200° . The authors have previously found that the point of ignition of these mixtures is 650° , but at the same time they are inflamed slowly. It is probably owing to this slowness of inflammation, combined with the expansion and consequent extremely rapid cooling which the gaseous products of the detonation undergo, that the great difference between 2200° and 650° is due.

The commission has thus been able to prepare mixtures of explosives which were incapable of igniting fire-damp mixtures when detonated unconfined in their midst. To determine what composition such mixtures should have, it was found sufficient to assure one's self that their temperature of detonation, when calculated with Berthelot's thermo-chemical data and Mallard and Le Chatelier's value for the specific heats, was below 2200° .

It is by such means that the commission has proved by numerous experiments that mixtures of dynamite with equal weights of crystallized sodium carbonate, sodium sulphate with 10 molecules of

water, ammonium alum and ammonium chloride, will not inflame fire-damp mixtures in the midst of which they are detonated. They produce the same effect on dynamite detonated in coal-dust mixtures.

The mixtures formed on adding ammonium nitrate to nitroglycerine or to gun-cotton are particularly advantageous because the nitrate itself acts as a detonant, while it lowers the temperature of the detonation to nearly its own detonation temperature, which is 1130° , whilst that of dynamite is 2940° , that of nitroglycerine is 3170° and that of cellulose endecanitate is 2636° .

The commission finds that mixtures of dynamite or nitroglycerine with 80 parts of ammonium nitrate, and naturally mixtures which are richer in nitrate, do not ignite the marsh gas mixtures, and that it is the same with mixtures containing in 100 parts 20 parts or less of a cellulose nitrate whose nitrogen dioxide contents is less than 193 cm^3 .

Cartridges made of different mixtures according to the general principles indicated here have been submitted to numerous trials, and they are to be tried on a large scale in the mines, where it is hoped to realize great safety.

U. S. Letters Patent No. 393794, December 4, 1888, have been granted George French for a "Method of Blasting," to be used in coal mines and similar places, to prevent firing the gases in the mine when the explosion occurs, and which consists in surrounding the charge in the bore-hole with a fire-extinguishing powder composed of sawdust wet with the following mixture: Alum, 5.1 per cent; sal ammoniac, 1.7 per cent; salt, 10.2 per cent; water, 83.0 per cent.

This solution is incorporated with the sawdust in about the proportions of two parts of the former to one of the latter, and three-fourths of one per cent of black lead is added. The powder is stored for use in the damp state, so that it binds together when exposed to pressure and is thus easily consolidated around the blasting charge. It is held that a great advantage results from employing a powdered composition in place of water or jelly-like substances, since the powder is separated more readily and is more completely distributed, while it may be rammed around the blasting charge without the interposition of waterproof linings and the like.

The claim is for "the method of blasting consisting in making a bore-hole, inserting the blasting charge therein, ramming around the blasting charge sawdust or like absorbent powder saturated with a solution of alum, salt and sal-ammoniac, or an equivalent salt solu-

tion, and then firing the charge in the bore-hole when thus surrounded with the said powder."

The *Ber. Berl.* **22**, 18-23; 1889, contains the results of L. Meyer's studies of the process of "Nitration." He finds that the quantity of nitrobenzene formed in a given time by the action of a given volume of nitric acid on benzene is greater the less the quantity of benzene present; for example, 100 mols. of nitric acid and 100 mols. of benzene yield 17 mols. of nitrobenzene in 15 minutes at 3°; but when 300 mols. of benzene are employed, the quantity of nitrobenzene produced is 10.02, and when 700 mols. of benzene are used, only 3.6 mols. of nitrobenzene are produced in the same time under exactly the same conditions. The results are similar when small quantities of benzene mixed with a constant quantity of nitrobenzene are treated with a constant quantity of nitric acid. A mixture of 100 mols. of nitric acid and 5 mols. of benzene diluted with 100 mols. of nitrobenzene yielded 4.4 mols. of nitrobenzene in 15 minutes at 3°; as the quantity of benzene was gradually increased from 5 to 100 mols., the quantity of nitrobenzene formed in the same time and under the same conditions gradually decreased from 4.4 to 2.2 mols.

When a mixture of 100 mols. of benzene and 100 mols. of nitrobenzene is treated with quantities of nitric acid varying from 50 to 450 mols., the quantity of nitrobenzene produced in 15 minutes at 3° is proportional to the square of the quantity of the acid employed. The quantity of acid decomposed is almost proportional to the quantity added, the increase being about 2.55 per cent on the average for each additional 50 mols. of acid. The quantity of nitrobenzene produced in 15 minutes at 3° is expressed very closely by the formula,

$$N = 5.1(A/B)^2 - 2.9A/B$$
 where A is the number of molecules of acid, and B the number of molecules of benzene in the mixture.

Nitrobenzene retards the reaction between nitric acid and benzene far more than benzene does, and even to a greater extent than an equivalent quantity of water, but less than an equal volume of water. As soon as the volume of water produced becomes equal to that of the anhydrous acid present, the reaction ceases, so that at least 2 mols. of acid are required to nitrate 1 mol. of benzene, unless sulphuric acid is also added. If the proper quantity of anhydrous acid is employed in nitrating benzene, equilibrium is established very soon, even in the cold; but if the acid is not quite anhydrous, or if

excess of benzene or nitrobenzene is present, hours or even days are required to complete the reaction, and in any case the nitration, which is most rapid at first, gradually decreases. For example, with a mixture of equal molecules of nitric acid, benzene and nitrobenzene at the average temperature of 18° , the reaction was not finished until after 71 hours' time; 50 per cent of the benzene had by this time changed, but even then there was a slight subsequent reaction.

A table is given showing the quantity of acid decomposed after various lengths of time, when quantities of benzene varying from 25 to 150 molecules are added to a mixture of 100 molecules of nitric acid and 100 molecules of nitrobenzene. The table shows that in the experiments with 25 molecules of benzene, the conversion into nitrobenzene is complete in half an hour, and that then the formation of dinitrobenzene commenced. In the other experiments the reaction proceeded at first the more quickly the smaller the quantity of benzene present, this difference gradually becoming less and less the nearer the process reached the point at which half the acid is decomposed.

In their investigations upon the "Constitution of the Jute Fiber-substance" or lignocellulose (*J. Chem. Soc.* 55, 199-213; 1889), Cross and Bevan have, among other reactions, noted the effect of the time of exposure on the products obtained by nitration.

In the first experiment cited they used raw jute fiber and a nitrating acid formed of equal volumes of nitric acid (sp. gr. 1.43) and sulphuric acid (sp. gr. 1.8). The temperature being 18° , they obtained the following results:

I. Duration of exposure.	Yield per 100 parts of fiber.
1 minute.	125.2
2 "	129.2
3 "	140.0
4 "	149.0
15 "	146.0 secondary actions with conversion
16 hours.	131.0 into soluble products.

In three other experiments the nitrating mixture was: II. As in I; III. Equal volumes of nitric acid 1.5 sp. gr., and sulphuric acid 1.8 sp. gr.; IV. Nitric acid sp. gr. 1.5, one volume, and fuming sulphuric acid 0.75 volume. Besides this, two varieties of fiber were used: A. Raw fiber such as was used in I; and B. the modification

resulting from the action of hot dilute hydrochloric acid upon this fiber. The duration of exposure in all cases was 30 minutes at 18°. The yield of nitrate per 100 parts of dry fiber was:

	II.	III.	IV.
A	144.4	153.3	154.4
B	143.8	152.8	152.7

A reaction according to the equation $C_{12}H_{18}O_9 + 3HNO_3 = 3H_2O + C_{12}H_{15}O_6(NO_3)_3$, is equivalent to a gain in weight of 44 per cent; the conversion into the titranitrate, 58 per cent. The formation of the latter appears, therefore, to be the limit of nitration of the jute fiber; in other words, if we represent the lignocellulose by a C_{12} formula, it will contain four alcoholic OH-groups, or two less than cellulose similarly represented.

To confirm the composition of these products and the equations above given, the specimen IV A was analyzed by Eder's method (*Ber.* 13, 109) with the following result:

0.453 gram gave 82 cm³. NO at 19° and 770 mm.; whence N = 10.5 per cent. Calc. $C_{12}H_{15}O_6(NO_3)_3$, N = 9.5 per cent; $C_{12}H_{14}O_6(NO_3)_4$, N = 11.5 per cent.

These nitrates resemble those of cellulose in all essential points. There is no evidence of any resolution of the molecule attending its combination with the acid radicle; the product is a nitrate of the lignocellulose, which again manifests itself as a chemical individual.

Patent 4310, March 20, 1888, has been granted in England to E. Turpin for an improved smokeless powder for firearms, which is prepared by dissolving gun-cotton more or less nitrated in any solvent most suited to the kind of gun-cotton employed, *e. g.* "nitrobenzene and other nitro-bodies of the aromatic series, aniline, aldehydes, amido-compounds of various kinds, acetone, sulphuric, nitric, acetic, and other ethers." Also "ammonia in solution in sulphuric or other ether, acetone in solution in sulphuric or other ethers or mixtures of ethers are suitable for dissolving gun-cotton more or less nitrated."

The resulting paste is spread upon plates or trays with raised edges and allowed to dry. When sufficiently dry the sheets are rolled out to the desired thickness, and subsequently cut crosswise by suitable machinery, in order to form small cubes. The rapidity of combustion of the powder is retarded by the addition of camphor, nitrobenzene, nitrotoluene, paraffine, etc. By varying the proportions

of the ingredients above named, "powders may be obtained adapted to suit all requirements."

A. Nobel has been granted Eng. Pat. 1470, Jan. 31, 1888, for a safety fuze, which is made of a celluloidal substance in the following manner: To 100 parts (by weight) of nitroglycerol 15 to 20 parts of camphor are added, and the solution thus obtained is thickened by dissolving 6 parts of nitrated pulped cotton in it. Seventy parts of potassium chlorate, 25 parts of potassium ferrocyanide, and 44 parts of soluble nitrate are then added, and the whole thoroughly incorporated to produce a substance of the consistency of soft India rubber and easily workable into thread. The advantages claimed for this fuze are absolute continuity, imperviousness to moisture, and absence of smoke when ignited.

English Patent 15771, Nov. 17, 1887, has been granted F. Crane for improvements in and connected with varnishes, which consist in using a solution of shellac in combination with a solution of pyroxylin in a practically non-hygroscopic menstruum miscible with the shellac solution.

English Patent No. 487, Jan. 12, 1888, has been granted A. Orr for improvements in forming solutions and compounds of nitrocellulose. The solvent employed is "a chlor-acetate of chlor-amyl," prepared by the action of chlorine on fusel oil "and other chemicals," and may be diluted with from 2 to 5 parts of fusel oil. A solution of nitrocellulose in this solvent mixed with castor oil and "wood pitch" is said to give, by suitable treatment, a very good insulating material.

In a paper entitled "An Improvement in the Manufacture of Chlorate of Potash" (*Jour. Soc. Chem. Ind.* **8**, 168-173; 1889) M. J. Hamill describes in detail, with illustrations and tables, the method he employs of refrigerating the mother-liquors so that the yield is increased about one-seventh.

In his study of the "Hydrazine Sulphonic Acids and the Triazo-Compounds," *Ber. Berl. Chem. Ges.* **21**, 3409-3423; 1888, H. Limp-richt has obtained the following explosive compounds: Barium metatriazobenzenesulphonate, $\text{Ba}(\text{C}_6\text{H}_4\text{N}_3\text{SO}_3)_2$, which crystallizes in slender, colorless needles, and explodes when heated to 130° ; potas-

sium triazonitrobenzenesulphonate, $\text{K.C}_6\text{H}_3.\text{N}_3.\text{NO}_2.\text{SO}_3$, which crystallizes in light brown plates, is very unstable, is readily soluble in hot water, and explodes when heated to 130° ; diazotriazobenzene-sulphonic acid, $\text{C}_6\text{H}_3.\text{N}_3\text{<SO}_3\text{>N}$, which is obtained in orange-red crystals that turn dark blue on exposure to the air, and explode violently both through percussion or heat; diazodibrombenzenesulphonic acid, $\text{C}_6\text{H}_2.\text{Br}_2\text{<SO}_3\text{>N}$, obtained in yellow crystals, which are very sparingly soluble in cold water, are decomposed by boiling water, and explode violently when heated; barium triazodibrombenzenesulphonate, $\text{Ba}(\text{C}_6\text{H}_2.\text{Br}_2.\text{N}_3.\text{SO}_3)_2$, crystallizing in pale red plates which are sparingly soluble in cold water; hydrazinebenzenedisulphonic acid, $\text{NH}_2(\text{C}_6\text{H}_3.\text{NH.N.SO}_3\text{H.OH})_2$, crystallizing in fine, lustrous yellow rhombs, insoluble in most of the usual solvents; and barium triazobenzenedisulphonate, $\text{Br}(\text{C}_6\text{H}_3.\text{NH.N}_2.\text{SO}_3.\text{OH})_2.3\text{H}_2\text{O}$, which crystallizes in yellowish plates that decompose slowly at ordinary temperatures.

Among other "Aromatic Lead Compounds," A. Polis has obtained a basic lead ditolylnitrate ($\text{HO.Pb}(\text{C}_7\text{H}_7)_2\text{NO}_3$) in the form of a white amorphous powder which explodes slightly when heated.—(*Ber. Berl.* **21**, 3424-3428; 1888.)

Eng. Pat. 11537, August 24, 1887, was granted O. Bowen, A. S. Tomkins and J. Cobeldick, for improvements in the manufacture of charcoal, the object of the invention being to produce a charcoal rich in hydrogen and suitable for the manufacture of gunpowder. For this purpose wood or suitable carbonaceous matter is subjected to a heated current of air mixed with hydrogen. The furnace employed has been described in Eng. Patents 509 of 1881 and 1457 of 1886.

German Patent 44078, December 19, 1887, has been granted to H. Güttler for further improvements in his charcoal furnace, the wood being introduced in the form of pulp. The improved apparatus cannot be described in the absence of drawings, but it seems to be an important addition to this special branch of powder manufacturing.—(*Ding. poly. Jour.* **270**, 215; 1888.)

The *Moniteur de la Photographie* of Paris calls attention to a

dangerous explosion of ether which occurred while this liquid was being carefully evaporated in a platinum dish, after having served for extracting grease. The ether was very old, having been kept in a stock bottle for many years, and probably exposed to light. It contained no less than five per cent of hydrogen peroxide, to which the explosion is ascribed, and a little acetic and formic acids.—(*Pop. Sci. News* 22, 38; 1888.)

Science 13, 152; 1889, copies from the *Ottawa Journal* a notice of a rather unique phenomenon, known as a "Sawdust Explosion," which is a breaking up or bursting through of the ice that occasionally occurs on the Ottawa river, Canada, and is supposed to be due to the sudden liberation of immense quantities of marsh gas which has been generated by the sawdust that has been thrown from the sawmills at this place, and is accumulated in the bed of the river. The gas is said not to be ignited. No proof of the existence of the gas other than the bursting of the ice is given.

Mr. Wolcott C. Foster contributes to the *Eng. News* 21, 29; January 21, 1889, "A Classification of Explosives," which he offers in lieu of those in use. The scheme is, however, faulty in many particulars and ought not to be followed. Among others we may note that although Class VII is styled "Fulminates," Class VIII is styled "Chemical Compounds," nitrogen iodide and panclastite (*sic*) being given as examples. Again, for Class IV "Nitro Powders," we have the organic nitrates, mannitose and saccharose nitrates, as examples, while no provision is made for the large number of nitro-substitution compounds which are now coming into prominence.

A "Catechism of Explosives," by Charles E. Munroe, which is intended for use in the instruction of seamen-gunners, has recently been issued from the press of the Torpedo Station.

Ernst and Korn, Berlin, 1888, announce "Das Wesen und die Behandlung von brisanten Sprengstoffen."

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

JULY, 1889.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XXI.

Several U. S. patents have been recently granted to James Weir Graydon for inventions which relate to the use of high explosives for war purposes. U. S. Patent No. 399882, March 19, 1889, is for "A Revolving Air-Gun" for throwing dynamite or other high explosive projectiles, the object of the invention being the production of a gun in which, by the simple turning of a crank, the projectiles may be automatically placed in the barrels, the barrels revolved, and the projectiles discharged under a predetermined regulated degree of air pressure.

U. S. Patent No. 399883, March 19, 1889, is for a "High Explosive Charge," which is to be made by soaking woolen or cotton cloth or like fabric in nitro-glycerine until saturated, and coating the whole with paraffined paper, which is cemented to the cloth, or with shellac or any coating which will prevent the exudation of the nitro-glycerine. The cloth may be in sheets or in ribbons, and the charges may be made up by rolling up the fabric into cylinders. When in ribbons, the charge may be made up by placing the tape-like disks on one another.

U. S. Patent No. 399881, March 19, 1889, is for a "Shell" for use with powder-guns. This shell is to be charged with the tape-like disks (described in the last mentioned patent) of "dynamite cloth," as

* As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. Address *Torpedo Station, Newport, R. I.*

the inventor calls it, the shell having been previously lined with finely pulverized niter placed between two layers of cloth or other suitable fabric, which are protected from the moisture of the atmosphere by shellac or other similar material. The niter is used because, while it will "prevent heat engendered by the explosion of the propelling charge in the gun from reaching the bursting charge," it will also, "when subjected to the very much higher degree of heat produced by the explosion of the bursting charge, be converted into a gas, thus adding to the force of said charge." The niter is stated to resist a temperature of over 600° F., but when subjected to a temperature of above 644° F. it evolves oxygen gas freely, and this gas, mingling with the gases produced by the high explosive, will render the latter very much more effective.

Besides this and other features there is a flexible porous sack cemented to the point of the shell, and this sack is filled with oil. When the shell moves, the air pressure forces the oil out so as to lubricate the gun and shell and reduce the friction.

U. S. Patent No. 399877, March 9, 1889, is for a "High-Explosive Shell" for air-guns, the object being to provide a projectile which can be readily loaded and unloaded, and in which the density of the bursting charge may be equalized throughout the length of the charge chamber. He seeks to secure this by means of a perforated metal tube which fits in the center of the shell and runs the entire length, and which has secured to its exterior surface and throughout its entire length a continuous spiral sheet-metal flange or vane, this vane being also perforated. The interior of the tube contains the fulminate charge, while the high-explosive charge is coiled between the spiral vanes.

This high-explosive charge is the subject of another application, Serial No. 287630, October 9, 1888, and it consists of a flexible tube of some absorbent material, such as cotton or linen, which is filled with the dynamite or other high explosive. It is stated that when the charge thus put up is required for use, it is preferable to saturate the tube with nitric acid in order to convert it also into an explosive. This form of explosive is designed both for torpedo and artillery purposes.

U. S. Patent No. 399876, March 19, 1889, is for a "Circuit-Closing Device for Electrical Torpedo Fuzes," the peculiarity of which resides in the fact that it is to be operated by the pressure of the water when the torpedo has reached a predetermined depth.

U. S. Letters Patent No. 401851, April 23, 1889, has been granted H. W. Parsons for a "Distributor for Explosive Bombs,"* which consists of a frame carrying the desired number of bombs, and which is so controlled by electricity that any desired number of the bombs can be released at any desired time. It is intended that the distributor shall be attached to a balloon or float suspended in mid-air and operated from the ground.

From a private communication we learn that the insensitive nitroglycerine employed by Mr. S. D. Smolianinoff in the experiments described in these Notes (*Proc. Nav. Inst.* **13**, 573; 1887) is now styled *Americanite*.

U. S. Letters Patent No. 396739, January 29, 1889, were granted G. C. Gillespie, of Brooklyn, N. Y., for a "Machine or Engine for the Application of Explosive Energy to Mechanical Power," in which he states that the primary object to be attained in the construction of any machine operated by the sudden generation of high-pressure gas—as, for example, when gun-cotton is exploded—is to provide a means of controlling the power at the outset, and thus preserve the apparatus from any destructive shock. This object he claims to accomplish by the use of a cylinder and plunger, both of which are movable instead of one being fixed, as in the case of ordinary steam or gas engines.

Another important point, he states, to be provided for is the prevention of overheating, and this he claims to accomplish by the use of single-action cylinders which are drawn completely away from the plungers at each downward stroke, thereby enabling the gaseous products of the explosion to escape freely, and thus exert a cooling effect by their expansion.

A lecture on "Recent Inventions in Gunpowder and other Explosives" was delivered on Friday, the 5th of April, 1889, at the Royal United Service Institution, by Mr. W. H. Deering, F. C. S., F. I. C., Chief Assistant Chemist to War Department. The author referred first to brown or cocoa powder,† which was introduced in Germany, in 1882, in the well known form of a hexagonal prism with a central cylindrical hole. Its composition differs widely from the black powders then in use, being 79 per cent potassium nitrate, 3 per cent sulphur, and 18 per cent of a very lightly baked brown charcoal.

* *Vide* *Proc. Nav. Inst.* **13**, 412; 1887. † *Ibid.* **11**, 283; 1885; **13**, 658; 1887.

Prismatic brown powder, which is used in the larger English breech-loading guns, is of this composition, very slightly carbonized straw being used for the brown charcoal. For the same muzzle energy, this powder causes less pressure and less smoke than black gunpowder of the old composition. From investigations into the products of combustion in each case, it is found that in the brown powder there is present more of the oxidizing niter absolutely and relatively to the reducing charcoal and sulphur than in the black powder; thus the residue of the former is fully oxidized, and the gases contain only 7 per cent by volume of unoxidized or imperfectly oxidized constituents, while the residue of the black powder contains some 24 per cent of unoxidized constituents, and the gases 22 per cent. The volume of the gases produced in each case is about the same, but the temperature in the case of the brown is greater than in that of the black powder; hence it follows that the diminished pressures produced by the former must have been due to its slower rate of burning, which depends on its chemical composition.

Sir F. Abel and Captain A. Nobel have experimented with a mining powder, which is interesting as an example of the influence of a change of composition in the opposite direction to that of brown prismatic powder. Its ingredients are: niter, 61.92 per cent; sulphur, 15.06 per cent; charcoal, 21.41 per cent; and water, 1.61 per cent. The products of combustion are much richer in unoxidized products than those of the pebble powder, and the temperature is less. They have come to the conclusion that the gunpowder which gives most gas and least heat causes the least erosion in steel tubes. In view of this statement, it would be interesting to know how a powder of the composition of this mining powder, in the form of prisms of the usual shape and size, would behave as a gunpowder, and whether satisfactory ballistic results and less erosion would be obtained with it.

The lecturer next dealt with nitrate of ammonium gunpowder, and referred to the so-called amide powder* of Mr. F. Gaens, which has the following composition: 101 parts by weight of ordinary niter, 80 parts nitrate of ammonium, and 40 parts charcoal. It is claimed that in ignition, potassamine (KH_2N) is formed, which is volatile at high temperature and increases the useful effect of the explosive; that there is very little residue; that no injurious gases are generated, and that little smoke is produced. It is, however, open to question

* Proc. Nav. Inst. 13, 593; 1887.

whether the potassamine is really produced, or whether the products of combustion are not similar to those obtained from ordinary gunpowder. The powders referred to in Krupp's last report (No. 53, October, 1888) probably contain nitrate of ammonium, as may be deduced from the published accounts of their trial. Both those for small and large guns gave better results than the German service brown powder, and they were all very hygroscopic. A similar powder seems to have been used with the Swiss Hebler rifle. E. X. E. powder and S. B. C. powder were also mentioned as having been tried against English brown prismatic powder for heavy guns, with more or less satisfactory results. Perforated cake powders were mentioned as applications of the principles introduced by the American General Rodman in 1862, as also the efforts that have been made to obtain a charcoal of uniform chemical composition, either by the method of blending or by using uncharred turf or bog stuff.

Next, the interesting subject of smokeless powders* was reached. Within the last three or four years, several preparations which have been stated to give practically no smoke have been proposed as substitutes for the the old niter, sulphur and charcoal powders. They consist essentially of nitro-cotton or other kind of nitro-cellulose, specially treated with a view of producing a slower burning substance; or of nitro-glycerine and nitro-cotton. It was to be noted, however, that the presence of metallic nitrates would be incompatible with their smokelessness. This the lecturer exemplified by experiment. By the use of a suitable preparation of nitro-cellulose, or similar chemical compound, a practically smokeless powder is attainable, giving, with less weight of charge than ordinary gunpowder, very high velocity to the bullet, and making the cartridge of the small-bore rifle a little lighter. Vieille's powder (or "Poudre B"), which is used for the French Lebel rifle of 0.315-inch caliber, is stated to give to the bullet, which weighs 231 gr., a muzzle velocity of 1968 ft. sec., or, according to another statement, 2034 ft. sec., and to produce little or no smoke. Several patents have been taken out in England for various methods by which it is sought to slow down ordinary service gun-cotton (trinitro-cellulose) so that it can be used in a firearm without producing enormous initial pressures. Thus, in the Johnson-Borland powder the salient feature consists in forming nitro-cellulose into grains or prisms, which, after being dried, are saturated with a solution of camphor in a volatile solvent such as will evaporate below

* Proc. Nav. Inst. 13, 593 and 594; 1887; 14, 161, 438, 759-760; 1888; 15, 312; 1889.

100° C. This solvent is distilled off by a gentle heat and recovered, and the camphor is left in the solid state, intimately mixed with the nitro-cellulose. The material is then heated in a closed vessel, when the camphor exercises a remarkable gelatinizing effect on the nitro-cellulose, the hardness being regulated by the amount of camphor used, and not being merely on the surface, but extending throughout the mass. This peculiar property of camphor has long been utilized in the manufacture of celluloid. Engel, Glaser, and Turpin have also patented processes, and in all three the nitro-cellulose is dissolved or gelatinized in a solvent, by which treatment the fibrous character of the material is destroyed and a horny product obtained, burning in the rifle or gun at a slower rate than in the fibrous condition. Another powder of this class is that of Mr. A. Nobel, the founder of the nitro-glycerine industry. It is a horny preparation, composed of nitro-glycerine, nitro-cotton, and camphor. It is a kind of blasting gelatine, with the proportion of nitro-cotton greatly increased, and with the addition of camphor. The resulting product resembles celluloid in appearance, is easily formed into grains or pellets of any shape, and, it is claimed, burns in firearms slowly enough to render it a fit substitute for gunpowder, over which it is said to have the advantage of greater power, of leaving no residue, and of being practically smokeless. The permissible range of variation of the constituents is a wide one. Two examples of mixtures are given, representing the extremes of variation. In 100 parts by weight of nitro-glycerine, 10 parts of camphor are to be dissolved and 200 parts of benzol added. In this mixture, 50 parts of dry soluble nitro-cotton pulp are to be steeped. The benzol is then evaporated, and the material mixed by passing between rollers, which are hollow, and heated by steam to 50° C. or 60° C. When uniform, it is rolled out into sheets, and cut up into grains or moulded. Or, when it is required to reduce the amount of nitro-glycerine as far as practicable, 100 parts by weight of nitro-glycerine, 10 to 25 parts of camphor, and 200 to 400 parts of acetate of amyl are mixed, and 200 parts of dry soluble nitro-cotton pulp are steeped in the liquid. The material is then kneaded into a paste, the solvent is removed by heat, and the dry material cut up into grains, as before.

The lecturer concluded by referring to the picrates. After mentioning the powders of Abel and Turpin, he proceeded to say that picric acid is the predominating constituent of "mélinite,"* intro-

* Proc. Nav. Inst. 12, 616; 1886; 13, 581; 1887; 14, 151, 435 and 755; 1888.

duced into service use in France, in 1886–87, for charging shells. It is probable that ether is one of its constituents, its use being to cement together picric acid grains by means of collodion, a solution of dinitro-cotton in ether and alcohol. It is questionable whether the quantities of carbolic acid available for the manufacture of picric acid would be sufficient to meet large and continued demands for the latter. The available supplies of cotton for making gun-cotton, and even of glycerine for nitro-glycerine, are much less likely to be affected by a run upon them than those of carbolic acid, which depend upon the amount of coal tar produced, mainly in gas making. From French and German statements it appears that a vault of concrete 10 feet thick, not covered with earth, which would act as tamping to the explosive, may be considered as almost invulnerable to the attack of mélinite shells.

A short discussion followed the lecture. Mr. Nordenfelt said that it was not a question as to whether we should adopt a smokeless powder, but which smokeless powder should we adopt. Sir F. Abel pointed out the difficulties in selection, and the caution that is necessary; while the chairman wound up the discussion by reporting some extremely interesting ballistic results, transmitted to him from Elswick. It appears that the "velocity pressure curve" obtained there with the Chillworth special powder is almost ideal in its perfection. With the 4.7-inch gun, firing a 45-pound projectile, a muzzle velocity of 1990 ft. sec. was obtained with $13\frac{1}{2}$ tons pressure. In our new rifle, the black pellet powder is to give a velocity of 1810 ft. sec. with 18 to 19 tons pressure; but with a powder known as the R. C. P., employed at Elswick, with the same pressure, a velocity of 2050 ft. sec. was reached.—(*Industries* 6, 426–427; 1889.)

The valuable paper by Sir Frederick Abel and Colonel Maitland, on the "Erosion of Gun-barrels by Powder-products," which was published in the *Jour. Iron and Steel Inst.*, No. 2, 1886, has been reprinted in full in the *Notes on the Construction of Ordnance*, No. 46, published by the Ordnance Department, U. S. A.

English Patent 13656, September 21, 1888, has been granted C. F. Hengst for an "Improved Safety Smokeless Gunpowder," which is produced by nitrating pulped straw, and after removal of all traces of acid, granulating the product, with or without the addition of oxidizing agents.

English Patent 7608, May 25, 1887, has been granted Wohanka & Co. for "Improvements in the Manufacture of Explosives," which consist in adding cellulose to the liquid explosives, made by dissolving in concentrated nitric acid the nitro-derivatives of the hydrocarbons of the aromatic phenol series. The cellulose becomes nitrated and swells up, forming with the explosives a plastic mass resembling gelatin.

English Patent 18362, December 15, 1888, has been granted J. W. Skoglund for "Improvements in the Manufacture of Explosive Compounds," which invention relates to the manufacture of explosive compounds consisting of nitro-cellulose or trinitrophenol, together with the radical of carbonic, oxalic, or carbamic acids, in combination with ammonium or another volatile radical base or hydroxyl.

English Patent No. 5270, April 9, 1888, has been granted Le Vicomte Hilaire de Chardonnet for a "Process for Denitrating and Dyeing Pyroxilin," which consists in treating nitro-celluloses with nitric acid of a density of 1.32, whereby in a few hours they lose part of their nitrogen and become reduced below the state of the "tetranitrate," at the same time beginning to soften and being rendered more easy of treatment in dyeing and other operations.

English Patent 8253, June 8, 1887, has been granted F. Crane for "Improvements in Pyroxyline Compounds and Varnishes," in which propyl and butyl acetates alone, together, or mixed with benzene, light petroleum, acetone, methyl and ethyl alcohols, and amyl acetate, are used as solvents for pyroxyline for the manufacture of varnishes and lacquers and for the production of celluloid.

The advantages claimed for the propyl or butyl acetates are their good solvent powers, the sufficient but not too great rapidity with which they evaporate, their non-hygrosopic character, the ease with which they mix with the other substances mentioned above, and their comparatively agreeable odor.

English Patent 2694, February 21, 1887, was granted M. P. E. Gérard, Paris, for a composition capable of being formed into threads, films, sheets, slabs, or moulded articles, or used as a varnish, the composition of which is: Ten parts gun-cotton and five parts gelatin are separately dissolved in acetic acid, then mixed together. A small quantity of glycerine and castor oil, or in other cases a little gluten, glucose, or honey, is added to improve the com-

position. The addition of a trace of calcium chloride renders it unflammable. The product can be used as a varnish for wood, etc., and especially for plaster, and can also be moulded into articles of great delicacy of structure.

English Patent 5824, April 21, 1887, has been granted J. W. Knight and W. D. Gall for "Improvements in the Manufacture of Carbolic Acid and other Tar Acids," by which the carbolic oil is treated with lime and agitated with a hot solution of sodium sulphate, the carbolate of lime first produced being converted into carbolate of soda, with simultaneous formation of calcium sulphate. The watery liquid containing carbolate of soda is drawn off and decomposed with sulphuric acid. The carbolic acid rising to the top is then separated from the lower liquid, which consists of a solution of sodium sulphate ready to use for another treatment with a fresh quantity of oil. The exhausted oil may be passed through filters in order to remove the calcium sulphate.

U. S. Letters Patent No. 403749, May 21, 1889, have been granted J. A. Halbmayr for a method of "Manufacturing Explosives" from tar-oils, which consists in conducting the oils into a body of nitrating acid from below the surface of the latter in a state of division, and at the same time introducing cold air under pressure at the same point with the oils. This is accomplished by using a series of tall water-jacketed tanks filled two thirds full of fuming nitric acid, and reservoirs for the tar-oils which are placed at higher levels than the converting tanks, so that the oils can by gravity be forced into the bottom of the converting tanks, cold air being introduced under pressure at the same point. The nitro-derivatives rise to the top of the liquids in the converting tanks, and by suitable overflow pipes they may be removed. By using a series of these converters at different levels, the operations may be repeated so as to ensure more complete and thorough conversion of the lower or the production of the higher nitro-derivatives.

The Favier Company, in Belgium, have recently brought out a new explosive which consists of a mixture of mononitronaphthalene and ammonium nitrate. The cartridges which are made with this explosive are made waterproof by dipping in molten paraffin. The composition of the cartridge core is as follows :

	Per cent.	Per cent.
Mononitronaphthalene (not quite pure, melting point from 51° to 56° C.),	8.15	7.97
Ammonium nitrate,	91.55	91.83
Insoluble in water and ether,	0.14	0.20

Or, if the covering of paraffin be included in the analysis, they test thus:

	Per cent.	Per cent.
Mononitronaphthalene,	7.77	6.86
Paraffin (melting point 56° C.),	4.04	4.41
Ammonium nitrate,	88.01	88.09
Insoluble in water and ether,	0.22	0.34

One molecule of nitronaphthalene requires, theoretically, $2\frac{1}{2}$ molecules of ammonium nitrate in order to burn to carbonic acid, water and nitrogen. But if both the 4.41 per cent of paraffin and the 6.86 per cent of nitronaphthalene are oxidized completely, 144.62 per cent of ammonium nitrate is required, whereas the amount of ammonium nitrate present (88 per cent) is only sufficient to oxidize the carbon to carbonic oxide. Such an explosive is unsuitable for underground blasting. The new explosive is indifferent to concussion, and burns with difficulty. In order to cause it to explode, two grams of fulminate are required, but as this priming is about six times as expensive as the priming of a dynamite cartridge, it is questionable whether Favier's explosive can ever hope to compete with dynamite. Favier failed in obtaining a patent in Germany, nor has he been more successful in finding capitalists in that country inclined to work his "invention."—(*J. Soc. Ch. Ind.* 8, 519; 1889; from *Chem. Ind.* 11, 241.)

English Patent No. 8929, June 22, 1887, has been granted H. Güttler for an "Improvement in the Manufacture of Charcoal for Explosives and other Purposes, and Apparatus for that Purpose."* In the apparatus described, the material is suitably contained in an air-tight cylinder, which is fitted with a pressure gauge and pyrometer and heated by means of a muffle. The carbonization takes place in a current of heated carbon dioxide, and the pressure of the same in the cylinder can be varied at will. The temperature is regulated by admitting cold air to the muffle and by varying the supply of heated gas to the cylinder. After the charring is complete,

* *Proc. Nav. Inst.* 15, 314; 1889.

cold air is rapidly drawn through the muffle, and cooled carbon dioxide passed through the charcoal, which rapidly cools and absorbs the carbon dioxide in its pores. Charcoal treated in this manner is said to be proof against spontaneous ignition.

The *Jour. Soc. Chem. Ind.* 7, 488-489; 1888, contains a detailed account of the visit of the society to Nobel's Dynamite Works, near Stevenson, Ayrshire, and of the experiments with dynamite and blasting gelatin which were made on this occasion. On pages 490-493 of the same journal is a paper on the "Manufacture of Explosives as carried on by Nobel's Explosives Company." Besides nitroglycerine, dynamite and blasting gelatin, this company manufacture detonators and fulminate of mercury. It was claimed that the Stevenson factory was the largest dynamite factory in the world, and produced about eight tons of explosives daily.

U. S. Letters Patent No. 397285, February 5, 1889, have been granted to G. E. F. Grüne for a method of "Preparing Dynamite," which consists in first mixing kieselguhr with sugar, starch, cellulose and like substances, or blood, glue, casein and the like, then compressing the mixture into cartridges, which are then carbonized so as to obtain an intimate mixture of carbon and kieselguhr. These cartridges are then immersed in nitroglycerine until saturated, whereby they are converted into dynamite. It is claimed that this dynamite is water-resisting, and that these cartridges may be kept and transported under water without producing any diminution in their explosive power.

U. S. Letters Patent No. 398559, February 26, 1889, have been granted to J. Waffin for a "Dynamite." In manufacturing this explosive he first makes a mixture of

Sodium nitrate,	.	.	.	.	.	22.50 parts.
Decayed wood (well dried),	.	.	.	.	.	36.00
Picric acid,	.	.	.	.	.	.25
Sulphur,	.	.	.	.	.	1.00
Sodium carbonate,	.	.	.	.	.	.25

Next he mixes together

Nitroglycerine,	.	.	.	.	.	94.00
Collodion,	.	.	.	.	.	6.00

and then he takes 60 parts of the first mixture and 40 parts of the

second and mixes the whole together until the mass presents the appearance of a uniformly fatty substance.

English Patent 758, January 18, 1886, has been granted W. D. Borland for "Improvements in Explosive Substances and Absorbent Materials therefor." It is stated that the most porous forms of charcoal at present known will not absorb more than from 5-6 times their weight of nitroglycerol, in consequence of which large proportion of charcoal in the explosive, the gases produced by explosion contain too much carbonic oxide. By this improved process, a carbonaceous material is prepared capable of absorbing as much as 35 times its weight of nitroglycerol. The inventor carbonizes small pieces of cork waste or any form of cork in a convenient and suitable manner. "When properly prepared the carbonaceous substance readily absorbs from 7-8 times its weight of nitroglycerol, giving a pulverulent mixture; from 10-12 times, giving a plastic-like mass; and is capable of absorbing even so much as from 30-35 times its weight, yielding a stiff paste of homogeneous appearance from which no nitroglycerol separates, even after many months' immersion in water."

The mixture of 7-8 parts of nitroglycerol with one of the carbonaceous material is excellent for cartridges, and may be safely moulded under water. Mixed with one-fourth its weight of water it becomes absolutely unflammable, but may be detonated. A mixture of 75 parts of nitroglycerol, 3 parts of the carbonaceous substance, 2 of alkaline carbonate, and 20 of kieselguhr is extremely dry to the touch, less affected by freezing and thawing than ordinary kieselguhr dynamite, and may be immersed in water for an indefinite length of time without showing signs of exudation.

English Patent 3759, March 10, 1888, has been granted E. Kubin and A. Siersch for "Improvements in Explosives." "The object of this invention is to provide an explosive which, on being detonated, will prevent danger of ignition of fire-damp or coal-dust in mines."

For this purpose chloride or sulphate of ammonia, or the two salts together, are mixed with dynamite, blasting powder, or other explosive, in proportions varying from 20 to 50 per cent. On the detonation of the explosive the ammonia salts are decomposed into non-flammable gases, which have the effect of reducing the temperature and rarefying the explosive gases.

At the commencement of 1888 "The Flameless Explosives Company, Limited," was started in London. The flameless powder* is the invention of Hermann Schöneweg, of Dudweiler, near Saarbrücken, Germany. His invention consists in surrounding a blasting cartridge with a casing containing oxalic acid or oxalates, with the addition of oxygen-carriers, for the purpose of extinguishing the flame of the fuze and increasing the explosive power of the cartridge. It is mentioned in the prospectus of the company, that if an equal amount of the Schöneweg mixture (consisting of 75 per cent of ammonium oxalate and 25 per cent of potassium nitrate) be added to dynamite, blasting gelatine, or similar substances, no flame is produced on explosion; but this assertion has not been sufficiently tested. Besides, dynamite requires a far larger amount of potassium nitrate and ammonium oxalate than has been added in order to burn to carbonic acid, water and nitrogen, and, in the absence of these oxidizing agents, a large quantity of carbonic oxide, ammonia, and perhaps hydrocyanic acid would be given off. For this reason the author does not anticipate a great future for the flameless powder. Schöneweg did not succeed in having a patent granted to him in Germany. He has also conferred the working of his securite patent to the company mentioned. Securite consists of dinitrobenzol and ammonium nitrate. The Royal Mining Inspector, Margraf, testifies in the prospectus of the company to its being absolutely safe in the presence of marsh-gas and coal-dust, whereas the experiments of the Royal Saxon mining authorities gave the very opposite result.—(*Jour. Soc. Ch. Ind.* 7, 519; 1888.)

English Patent No. 5949, April 21, 1888, has been granted A. Kuhnt and R. Deissler for an "Improvement in Explosive Compounds," which consists in substituting for the water-cartridge at present in use in coal mines one made of nitroglycerine mixed with ammonium carbonate or chloride. "By the addition of this carbonate of ammonium (or chloride), the temperature of the explosive gases is so small that flashing of the gases is prevented."

U. S. Letters Patent No. 397440, February 5, 1889, have been granted L. Plom and J. d'Andrimont for a "Method of Blasting," which consists in making a cavity near to the end and on either side of the bore-hole, filling the lower part of this lateral cavity with the

* *Proc. Nav. Inst.* 14, 758; 1888.

explosive, and plugging the bore-hole with a wooden plug which carries the fuze. It is claimed that the explosive will thus be rendered more efficient, and that any tendency to blow out through the bore-hole will be prevented.

J. R. Eaton states that after making hydrogen phosphide in the usual way by boiling phosphorus in potassium hydroxide, he allowed the apparatus to remain *in statu quo* for three days, in order to show his class that the phosphorus remained in the liquid state after cooling, and at the end of this time finding it liquid, he lifted the flask and gave it a slight shake, when it immediately exploded and the phosphorus solidified at once. He suggests that it was due to gas being condensed by adhesion around the phosphorus as the solution cooled, and that the shaking caused a rapid evolution of this gas.

He states that nitrogen iodide will explode when wet,* if it has been allowed to stand twenty-four hours in aqua ammonia, and that when freshly prepared, if partially dried and then scattered over the surface of a tank of water, it will repeatedly explode for hours after by slightly agitating the water.

He many years ago used a mixture of potassium chlorate and phosphorus by placing the powdered salt (no more than will cover a nickel, if exploded within doors) upon a board, and wetting it with a solution of phosphorus in carbon† disulphide (an inch of phosphorus will dissolve in an ounce and a half of carbon disulphide in a few minutes). In from five to ten minutes, or as soon as the mixture is dry, touch it with a long pole, or even stamp on the floor, and a loud explosion will ensue. A quantity sufficient to cover a dollar will shatter a thick plank and make a considerable hole in the ground.—(*Science* **13**, 449; 1889.)

The high temperatures attainable with Dr. Hare's oxyhydrogen blowpipe have long been known to chemists, and its practical use in the "lime light" has been quite common. Formerly the gases were stored for use in tin gas-holders or rubber bags, and were forced out under a moderate pressure, but within the last decade it has become the custom to store the gases up in stout steel or wrought iron cylinders, under a pressure of many hundred pounds, and the supplying of these compressed gases has become a very considerable industry.

With the cheapening in the cost of the production of oxygen, the

* *Proc. Nav. Inst.* **12**, 424; 1887.

† *Ibid.* **15**, 85; 1889.

substitution of compressed coal gases for hydrogen, the continual improvements in methods and means for compression of the gases, and in the form and proportions of the blowpipe, it is not surprising to learn that new commercial applications are continually being found for it, and that in its present form it bids fair to rival in cheapness and to surpass in convenience the various electric methods which have recently been devised for autogenic welding. An account of some of the most recent advances will be found in a paper by Thos. Fletcher (*Jour. Soc. Chem. Ind.* **7**, 182-185; 1888) on a "New Commercial Application of Oxygen."

The explosiveness of these gaseous mixtures is one of the well known facts of chemistry, and several examples of accidental explosions have already been cited in these Notes,* but as the use of the compressed gases is increasing very rapidly and bids fair to become widely extended, we quote the following "Notes on the Explosion of Gas Cylinder," by W. N. Hartley, from the *Chem. News* **59**, 75-76; 1889:

On January 28 a lamentable and fatal accident happened to Mr. Thomas Arthur Bewley, by the explosion of a cylinder of compressed gas at the shipbuilding yard of Messrs. Bewley & Webb, East Wall, Dublin. The deceased gentleman established machinery for the compression of gases, and supplied the trade with compressed coal-gas and oxygen in wrought-iron cylinders. Owing to the uncertainty of the exact cause of the explosion, a good deal of anxiety has been excited amongst the public.

The combustible gas, whether hydrogen or coal-gas, was stored in cylinders painted red and the oxygen in cylinders painted black. This rule was intended to be invariable. On December 27, Mr. Chancellor, of Sackville Street, sent an urgent request for a bottle of oxygen, but there being none of the black cylinders available, owing to the excess of business at Christmas time, Mr. Chancellor was informed that he could be accommodated with oxygen in a red cylinder. This cylinder was returned on January 15. Afterwards, an application was made for a bottle of hydrogen and one of oxygen. It had been forgotten by the deceased that this bottle was charged with oxygen, and, being red, it was simply filled up and sent out as hydrogen.

It was attached to a lime-light apparatus when the discovery was

* *Proc. Nav. Inst.* **14**, 166-167; 1888.

made that it contained mixed gases, for the india-rubber connecting tube was blown off as soon as the gas was ignited at the burner. It was placed on one side and labeled "mixed gases." Two days afterwards the bottle was sent back to Mr. Bewley and was placed on a table in the drawing office, where it remained until the fatal occurrence.

Instead of allowing the gas to blow off, he tested a small quantity of the gas in a tube in presence of one of his foremen, who described the "spirt" with which it went off when a lighted match was applied to the mouth of the tube. The flame seen was a small blue one. He stated to the foreman that, as the amount of inflammable gas was so small, he intended to use the cylinder himself as an oxygen cylinder. As the pressure was higher than he required, a portion of the gas was allowed to pass into another black cylinder, which reduced its tension from 800 to 400 pounds (the breaking strain of the bottle is well over 2000 or 2500 pounds). It must be remarked that the connecting tube did not fit satisfactorily, and that at the time (2 o'clock) a small gas-jet was burning in the room. At 4.25 the explosion occurred, but as no one had been in the drawing office but Mr. Bewley himself, the conditions under which the explosion took place are not precisely known. The evidence, however, is fairly conclusive.

In the first place, it must be stated that the metal of the cylinder was perfectly sound, and in the interior there was no appearance either of oil or of rust. While the upper part of the cylinder was blown to pieces, the body of it struck the arch over a window and caused the wall to bulge; it then ricocheted apparently against the wall, and passed through a window opposite to where it had first struck. The upper end of the cylinder was found at a much greater distance from the building.

One witness, who saw a gauge on the bottle marking 800 pounds, believed that the cylinder had been overcharged, and that disruption occurred simply by the elastic force of the gas. Having examined the premises, I was in a position to state at the inquest that the nature of the explosion was most certainly that of a detonation. The table and drawers were splintered into match-wood, and the glass from the window, as it lay on the ground, presented the peculiarities of fracture which are characteristic of such an explosion.

The examination of the top of the cylinder just below the shoulder showed that the fractured metal at this part had a different appear-

ance from the other fractured surfaces. Instead of being bright it was burnt all the way round, that is to say, covered with magnetic oxide. Moreover, the medical evidence showed that death was caused by shock, and the force of the explosion threw the body out of the room. While the left hand was severed from the arm at four inches above the wrist, the right was charred, and singeing was noticed on the right leg, and the hair was crisp from the same cause.

Without doubt the explosion occurred from the detonation of mixed gases within the cylinder.

The valves of both cylinders, which had been connected by a tube previously, were found wide open. The ignition of the gases was most probably caused, not by any chemical action spontaneously taking place within the cylinder, but either by a leakage which was tested by applying a match, or, the leakage being serious, the gases were fired by a lighted gas-jet. It must be remembered that what was believed to be the same gas had previously exploded in the lime-light apparatus, merely blowing off the india-rubber tube, but the valve being but slightly open, the explosion was not communicated to the interior of the cylinder because the pressure was higher and the issuing gas was traveling at too great speed for the temperature of ignition to be maintained in the stream issuing from the small orifice in so large a mass of metal.

For the better understanding of this explanation I will refer to a very simple experiment. Carbon monoxide stored in a gas-holder under a pressure of six inches of water, cannot be burnt from an ordinary gas jet, but if the size of the orifice is enlarged to $\frac{1}{16}$ or $\frac{1}{8}$ of an inch, it can be made to burn when the pressure is somewhat reduced. There is no material alteration in the conditions of the experiment if the gas be mixed with air or oxygen. In fact, the temperature of ignition cannot be maintained in contact with the cooling mass which surrounds a small orifice, or with the gas under a very rapid rate of flow.

We cannot precisely ascertain the temperature of ignition or the rapidity of explosion of the mixture of gases contained in the cylinder, but it certainly contained a large excess of oxygen, and the conditions under which it was first found to be dangerous were different and less favorable to explosion than after the pressure was reduced.

The verdict of accidental death was coupled with a recommendation that the public should be protected from similar accidents by a Government stamp being fixed to all cylinders used for such purposes.

But greater safety would be secured by making the fittings for hydrogen and oxygen cylinders so entirely different that it would be practically impossible to charge a cylinder with the wrong gas.

In *Ding. Poly. Jour.* **267**, 416-419; 1888, is an article by L. Jawein and S. Lamansky, on the "Decrease of the Illuminating Power of Naphtha Gas by Admixture of Air, and the Explosibility of such Mixtures," which contains the results of an examination of such naphtha gas as is manufactured in Russia from naphtha and naphtha residues, for illuminating purposes. Owing to the difficulty of obtaining a general average sample of the gas, the experiments were all made on one day; the required amount of gas being led into a small gas-holder, which also contained the air for mixing. The explosibility of the different mixtures was ascertained by subjecting them in a eudiometer to the action of an electric spark, and the following results were thus obtained:

Vol. of Gas.	Vol. of Air.	Explosion.
1	4.9 — 5.2	None.
1	5.6 — 5.8	Feeble.
1	6.0 — 6.5	Violent.
1	7.0 — 9.0	Very violent.
1	10.0 — 13.0	Violent
1	14.0 — 16.6	Feeble.
1	17.0 — 17.7	Very Feeble.
1	18.0 — 22.0	None.

A mixture of naphtha gas and air is therefore explosive if gas and air be in the proportion of 1 to 5.6 — 17.7 by volume, or 1 to 85 — 94.4 by weight. Of course these figures are only accurate for the sample of naphtha gas experimented upon. After all, it is not likely that the figures will vary much with different naphtha gases, the proportion for marsh gas being 1 vol. of gas to 6 — 16 vol. of air.

We have already recorded in these Notes* the suggestion which has been made to employ a mixture of powdered magnesium and gun-cotton for use as a flash-light in photography, and we have since watched for the accidents which it seemed inevitable must follow. Recently we have learned through private channels that such an accident occurred in New York on the evening of May 1, 1889, while a photographer was attempting to take a picture of the Centennial

* *Proc. Nav. Inst.* 14, 443; 1888.

Arch. For this purpose he employed from six to seven ounces of the mixture, which was placed in a tin tube about six inches long and three and one half to four inches long. This tube was fastened on the end of a wooden handle, so it could be held above the head at arm's length, like a torch. On igniting the mixture and raising the holder above the head, an explosion ensued which was accompanied with a violent report. The photographer was thrown down and rendered unconscious, but fortunately (and probably because of the position in which the tube was held) he escaped with only severe burns on the face, arm and hand.

The *Journal of the Society of Chemical Industry* 7, 244; 1888, gives the following account of the trade in explosives in France in 1885-1886, as rendered by Her Majesty's Attaché:

"As regards imports, we should remember that gunpowder, gun-cotton, nitro-glycerine, picrates, and fulminate are all prohibited; that dynamite is allowed to enter at a duty of 2 francs 50 centimes per kilo under special regulations; and that loaded cartridges are admitted, under special arrangements, at a duty of 25 francs per 100 kilos.

"The imports of dynamite and loaded cartridges into France in 1886 were as follows: From Belgium, 68,605 kilos of dynamite, and cartridges, *nil*; from England, dynamite, *nil*, and 133 kilos of cartridges; from Italy, dynamite, *nil*, and 18 kilos of cartridges; from Switzerland, dynamite, *nil*, and 1458 kilos of cartridges; giving totals of 68,605 kilos of dynamite and 1609 kilos of cartridges.

"Belgium is the sole importer of dynamite.

"The exports of explosives have been as follows: Military powder, 994 kilos in 1886, and *nil* in 1885; sporting powder, 30,018 kilos and 13,924 kilos; mining and foreign trade powder, 833,164 kilos and 817,779 kilos.

"The production of dynamite and gunpowder is controlled by the Excise, and official returns show the sales to have been as follows: Sporting powder, 433,518 kilos in 1886 and 490,562 kilos in 1885; mining powder, 2,559,128 kilos and 2,815,258 kilos; military powder, 164,286 kilos and 171,888 kilos; powders sold of all kinds on the Swiss and Italian frontier districts of Corsica, Monaco, and Tunisia; 148,967 kilos and 100,193 kilos; dynamite, 396,618 kilos and 447,359 kilos; nitro-glycerine, 668 kilos and 774 kilos.

"The total amount of gunpowder that paid excise was 4,169,081 kilos in 1886, and 4,409,604 kilos in 1885.

“The excise on gunpowder gave 12,970,255 francs (£518,808) in 1886, as against 13,862,441 francs (£554,496) in 1885.”

The British consul at Palermo reports that the very unsatisfactory state of the sulphur trade, and of the low prices this article finds in the market, are causing great anxiety to the owners of sulphur mines and to those who trade in sulphur. For the last five years the prices have been steadily decreasing; and whereas at one time merchants insisted on a profit varying from 21 to 42 centimes, they are now only too glad to obtain a profit of 4 and sometimes 2 centimes. The reason for this is to be found in the fact that the production of the mineral during the last thirty years has been excessive, and at present the annual production has been from 600,000 to 700,000 quintals over and above the ordinary consumption. The consequence is that the sulphur accumulates at the mines and at the outports, thereby causing the owners to get rid of their produce at any price. Another circumstance that has tended to depreciate the value of sulphur is that Sicilians cannot be brought to bind themselves into companies or associations; and so the opportunity of being able to close their mines for a few years until the stock is all disposed of at a fair profit is lost.

The French *Bulletin du Ministère des Travaux Publics*, for November last, says that the total quantity of sulphur contained in the Sicilian mines before workings were commenced is estimated at 65,000,000 tons. The quantity produced from 1831 to 1885 is stated to be 8,353,091 tons, and previous to this period about two millions, making a total of 10,353,091. When it is considered that to obtain this quantity about fifteen million tons were turned over (as generally a third is lost in the treatment), it results that the quantity still available is at least 50 million tons, and supposing that the average production for the future should be maintained at about the same proportion as in past years, the Sicilian mines may continue to be worked for another century.—(*Jour. Soc. Chem. Ind.* 7, 139, 140; 1889.)

The yield of the sulphur mines in Northern Italy was 21,663 tons in 1887, as against 23,274 tons in 1886. The decrease is partly due to the diminished yield of the Boratella pits, which have been partly worked out, and to the collapse of the Cesena Sulphur Company, Limited, which has pretty well exhausted the basin of the Romagna. The company has spent large sums in the search for new places of

production, and in the attempt to work further those commenced by its predecessors, but without avail; and after a few years the company saw itself confined to the pits at Boratella. The production of the company of the Romagna shows a slight increase. The Montivecchio shaft, which belongs to this company, is not yet complete.

Permanent progress is noticeable in the provinces of Pesaro and Urbino. The new shaft in the mine of San Lorenzo, in Zolfinelli, has increased the daily yield of the latter to 200 tons of ore. The loss of work in the Boratella mines has caused many of the workmen to turn again to the old Casalbono mines, which they work in small gangs. The yield has so far only been moderate.

The treatment of the crude sulphur has undergone little modification. A new refinery with three ovens and 34 refining kilns has been erected at Porto Corsini, near Ravenna. It turns out 6000 tons a year. In 1887 the various refineries have produced 24,000 tons of ground sulphur, an increase of 3516 tons over last year. The exact quantity of finely ground sulphur produced is not known, but it probably represents $\frac{1}{2}$ of the total refined sulphur. The Albani Pit Company produces special preparations, and to meet the increased demand, especially for their acid sulphur, has induced them to enlarge their new mill at Fano. During the last wine season the Pesaro manufactory turned out 9500 tons of acid sulphur containing 0.22 per cent of sulphuric acid, and 1105 tons sulphur containing between one and eight per cent of copper sulphate.

The presence of the above quantity of sulphuric acid has been found the most suitable in the treatment of the vine disease. This acid is not added, as is done in some parts of Italy, but is a natural adjunct of the preparation. Artificial acidification does not yet appear to have been introduced in the factories.

Though almost the whole production was disposed of during the wine season, prices have been kept low by Sicilian competition.

The average price per centner for the year has been :

Crude sulphur,	8.75 francs.
Refined in loaves,	10.40
Sulphur in sticks,	13.00
Coarsely powdered,	13.10
Sublimed,	14.50
Acidified powdered,	17.65
Powdered and containing copper,	21.50
Flowers of sulphur, washed,	35.00

The following are the statistics for 1887 :

Province.	Number of Pits in Work.	Quantity of Crude Sulphur. Tons.	Total. Value. Francs.	Number of Workmen.		
				Grown up.	Under 15 Years.	Total.
Anicone.....	1	34	2,680	96	..	99
Forli	10	13,026	1,095,006	1,231	7	1,238
Pesaro and Urbino.	5	8,603	668,269	1,304	48	1,352
Totals.....	16	21,663	1,765,955	2,631	55	2,686

—(*Jour. Soc. Chem. Ind.* 8, 142 ; 1889 ; from *Chem. Zeit.* 12, 1659.)

The *Bulletin du Musée Commercial*, March 24, 1888, states that there are in Chili about 50 manufactories of nitrates. The total production of 47 of these factories during the month of December, 1887, amounted to 659,464 metric quintals, or 65,946 tons ; it was 67,745 for the month of November. Assuming that these figures were maintained for the other months, there would be produced in 1887 about 800,000 tons. This is almost double the amount exported by Chili in 1886 and 1885, when the syndicate of manufacturers decided to diminish the production.

The *Journal of the Society of Chemical Industry* 8, 152-153 ; 1889, states that the shipments of nitrate to the United States during 1888 were 472,500 bags, against 555,000 bags in 1887, 522,750 in 1886, 270,323 in 1885, and 437,234 in 1884. The quantity to arrive for Atlantic ports is 224,000 bags, against 239,000 in 1888, 238,500 in 1887. The total visible supply is 310,000 bags, against 301,940 in 1888, 311,266 in 1887. The quantity to arrive in Europe is 2,527,000, making the visible supply there 3,112,000 bags, against 2,927,500 bags in 1888, and 2,070,000 in 1887. The deliveries at San Francisco during last year were 60,000 bags, making the total deliveries in this country 515,000 bags, as against 534,347 in 1887 and 454,760 in 1886. In Europe the deliveries were 4,712,000 bags, making the total for the world 5,227,000, as against 4,164,347 in 1887, 3,522,260 in 1886, 3,278,686 in 1885, and 3,974,071 in 1884. Tables are given showing the condition of the trade with the United States and Europe annually from 1883 to 1889.—(*Eng. and Mining Journal*.)

A. Muntz and V. Marcano have been studying the "Proportion of Nitrates contained in the Rain in Tropical Regions," and they have examined 121 specimens from Caracas, Venezuela, which have

yielded them the following average weights of nitric acid per liter : Specimens from July, 1883, to July, 1884, 2.45 mgr.; specimens from January, 1885, to December, 1885, 2.01 mgr.; or for a general mean, 2.23 mgr. The richest specimen of rain (taken October 19, 1883) gave the enormous quantity of 16.25 mgr. and the poorest 0.20 mgr.

Comparing these results with those obtained in Europe we find that Boussingault obtained an average of 0.18 mgr. at Liebfrauenberg, Alsace, and Lawes and Gilbert obtained an average of 0.42 mgr. at Rothamsted, England.

The authors attribute the great richness of the rains in the equatorial regions to the high electrical tension and frequent discharges which occur there, and which serve to oxidize the atmospheric nitrogen.—(*Compt. rend.* **108**, 1062–1064; 1889.)

A second edition of “*Les Explosifs Modernes*,” by P. F. Chalon,* has appeared, which has been augmented by over one hundred pages, which are devoted to a dictionary, or rather an encyclopædia, of explosives, and which adds very much to the value of the book.

A new book by Lieutenant Max von Förster, superintendent of the gun-cotton factory of Wolff & Co. at Walsrode, is announced under the title “*Schiesswolle in ihrer militärischen Verwendung*,” Berlin, 1888.

The “*Lectures on Chemistry and Explosives*,” which were delivered by Charles E. Munroe to the officers under instruction at the Torpedo Station in 1888, have been issued from the Station press in the form of a large octavo of some 320 pages, together with plates illustrating the methods of manufacture of gun-cotton.

*E. Bernard et Cie., Paris, 1889, *vide* Proc. Nav. Inst. **14**, 773; 1888.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH,
JANUARY, 1890.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XXII.

United States Letters Patent No. 409943, August 27, 1889, have been granted Stephen H. Emmens for "Gun and Projectile for High Explosives," in which he claims to have invented "a new and useful improvement in apparatus for utilizing high explosives in warfare, (No. 2)." This invention is additional to his improvement in apparatus for utilizing high explosives in warfare,† set forth in his application for U. S. Letters Patent, filed January 27, 1888, serial No. 262172.

The present apparatus is especially designed and adapted for use by infantry and in small boats; and the invention consists in a novel combination of parts, whereby he claims to be enabled to lighten the apparatus to any required extent, and to support a relatively short powder-tube for the propelling charge within the guide bore of the torpedo by means of a tube in line therewith, that incloses the firing device, and is in turn supported by a simple stock in the form of a stake or the like. A drawing accompanies his specification representing an elevation of a torpedo-gun and a bird-torpedo, illustrating the invention.

The "firing mechanism," as he terms it, especially distinguishing the present weapon, comprises a wooden stock fitting into and sup-

*As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. *Address Torpedo Station, Newport, R. I.*

† Proc. Nav. Inst. 15, 289; 1889.

porting a metallic tube, and axially perforated and slotted at its front end to accommodate within said tube a rod, which is bent at right angles at its rear end to form a trigger that projects outward through a bayonet-joint slot in the stock and tube. The front end of this rod is fixed in a piston which carries a firing-pin, and between said piston and the front end of the stock is a spiral spring; hence when the trigger is pulled back and turned into the holding-notch of the bayonet-joint slot, said spring is compressed, and when the trigger is released the spring urges forward the piston, with its firing-pin, to explode the propelling charge. This is contained within a short "gun-cartridge shell" or powder-tube, which fits into the front end of said tube and is coupled thereto by a pair of bayonet-joints. Preferably the "powder-tube," as it is termed, is provided with a primer-recess in its breech end, and with an axial ignition tube extending forward from said primer-recess to the front of the propelling charge, which may be of any suitable explosive. The ignition-tube is filled with gunpowder, and the recess is provided with a suitable percussion primer. When the latter is exploded by the firing-pin a sheet of flame is produced within the tube, which ignites the propelling charge at its front end, so as to insure its perfect combustion and an effective discharge of the weapon.

The bird-torpedo comprises a tube fitting closely over the metallic tube and powder tube above mentioned, and plugged at its forward end by the screw-stem of a conoidal torpedo-head. In an external annular charge-space immediately behind the head and around said tube, cartridges of emmensite, or other high explosive, are arranged side by side to form the high explosive charge. By using cartridges of different lengths the size of the charge may be varied to any required extent. These cartridges are held in position by a collar and a cylindrical jacket, and they are fired by a time-fuze. The rear end of the torpedo-tube is provided with three equidistant wings. An annular screen is fitted to the metallic tube of the torpedo-gun immediately in front of the trigger to protect the hand of the person discharging the weapon from any escape of heated gases.

The drawing shows the weapon planted in the ground for firing, but any other mode of mounting may be employed, *e. g.* the stock may be clamped in a holding-tube on an ordinary swivel stand or gunwale attachment.

In conclusion he claims as his invention: In combination with a thimble-shaped projectile having an axial guide tube open at its

rear end and surrounded by an annular charge-space for high explosives, a short powder tube and a tube inclosing a firing device, coupled together end to end and fitted to the interior of said guide tube, and a stock fitted at its front end to the rear end of said firing device tube, substantially as described.

The *Ann. des Mines* 5, 197-376; 1888, contains a very valuable "Report of the French Commission for Explosive Substances on the Use of Explosives in Presence of Fire-damp," in which the authors state that having satisfied themselves, both from the results of previous investigations and in some preliminary experiments, that mixtures of coal-dust and air were not as dangerous as mixtures of marsh-gas and air, they have restricted themselves to the latter and more dangerous mixture. The experiments were conducted in a boiler which, by suitable arrangement, could be completely filled with a gaseous mixture of known composition, and the explosive under examination was suspended in the middle of the boiler and fired by the aid of electricity, the effect on the gaseous mixture being ascertained by the alteration in pressure observed on a pressure-gauge.

The marsh gas was prepared from sodium acetate and soda-lime and stored in a gasometer; it contained per cent 10.8 of air, 7.9 absorbed by bromine, no carbonic anhydride, and 81.3 of methane (by difference). The mixture introduced into the boiler contained generally about 10.3 per cent of methane; this approximates to the most explosive mixture, whilst a 6 per cent mixture verges on the limits of non-inflammability.

The first series of experiments were tried with unconfined explosives freely suspended in the gaseous mixture, this being the most dangerous condition; such experiments are useful to ascertain the actual safety of an explosive.

The explosives investigated were: *Ordinary powder*; *dynamite* containing 75 per cent of nitroglycerol and 25 per cent of silica; *Paulilles ammoniacal dynamite*, a mixture of varying proportions of nitroglycerol, ammonium nitrate, and of a carbonaceous substance destined to utilize the excess of oxygen produced by the detonation of the nitroglycerol and ammonium nitrate; *gun-cottons* of the general formula $C_{24}H_{40-n}N_nO_{20+2n}$, in which the maximum value of n should be 12, but which in practice does not exceed 11. The following table represents the number of cubic centimetres of nitric

oxide evolved from 1 gram of the various gun-cottons when examined by Schloesing's method ; the value of n indicates the composition :

	$n =$	cc. N_2O_2 .
Endecanitric cotton,	11	214
Decanitric "	10	203
Enneanitric "	9	190
Octonitric "	8	178
Heptanitric "	7	162
Hexanitric "	6	146
Pentanitric "	5	128
Tetranitric "	4	108

Military gun-cotton (205 cc. N_2O_2) corresponds approximately to the decanitric ; *mining gun-cotton* (193 cc. N_2O_2) to the enneanitric ; and a third gun-cotton (173 cc. N_2O_2) investigated, to the octonitric. Tests were also made with *blasting gelatine* consisting of gun-cotton and nitroglycerol, and with *dynamite gelatine* consisting of blasting gelatine mixed with some such substances as a mixture of potassium or sodium nitrate with charcoal or sawdust. All these when detonated completely under the above conditions, generally ignited the gaseous mixture, and must therefore be regarded as dangerous for use in mines where fire-damp may be expected. The last two compositions did not detonate completely in cold weather. Dynamite and also gunpowder even ignited the gaseous mixture when detonated in a Settle's water-cartridge.* *Hellhoffite*, a mixture of dinitrobenzene with $1\frac{1}{2}$ or $2\frac{1}{2}$ times its weight of nitric acid (made on the spot where employed, but not considered sufficiently convenient for use in mines) ; *Favier's explosive*, 9 parts of mononitronaphthalene with 91 of ammonium nitrate ; and *Bellite*, about 20 parts of dinitrobenzene and 80 of ammonium nitrate ; either did not explode at all, as was the case with the first two when freely suspended in air, or exploded incompletely, as in the case of bellite. Under exceptional circumstances, finely pulverized Favier's explosive was made to explode and then ignited the gaseous mixture ; but the detonating mixture used with this explosive is, however, of itself dangerous. Two powders consisting of gun-cotton and barium nitrate ignited the gaseous mixture, whilst a powder consisting of 60 parts of gun-cotton (175 cc. to 185 cc. N_2O_2), 30 parts of barium nitrate, 6 parts of saltpetre, 3 parts of gelose, and 1 part of paraffine,

* Proc. Nav. Inst. 14, 766 ; 1888.

only inflamed the gaseous mixture twice out of 14 times. Various experimental mixtures were now investigated. Dynamite with an equal weight of either crystalline sodium carbonate, sodium sulphate, ammonia alum or ammonium chloride, did not ignite the gaseous mixture, but with larger proportions of dynamite the ignition of the fire-damp generally ensued. Some interesting experiments were made with mixtures of coal-dust and dynamite. Three coals, containing respectively 40, 27.86 and 23.60 per cent of volatile matter, mixed with equal weights of dynamite, did not set fire to the marsh gas when exploded, even a mixture containing 4 of dynamite to 1 of the first coal in one experiment did not ignite it, but a mixture of 2 parts of dynamite with 1 part of a lignite (braunkohle) containing 62.4 per cent of volatile matter, ignited the inflammable gaseous mixture. Mixtures of 20 of dynamite with 80 of ammonium nitrate detonate freely in the air without causing ignition of the marsh gas; in this case both substances explode, but the temperature of the explosion of ammonium nitrate is lower than that of the dynamite, and therefore moderates the activity of the latter in the mixture. Mixtures of gun-cotton and ammonium chloride require so much of the latter to make them safe that they ultimately cease to explode at all. Mixtures of gun-cotton and ammonium nitrate become safe when the former, giving 173 cc. of N_2O_2 , does not constitute more than 20 per cent of the mixture. From these experiments it was concluded that simple explosives susceptible of igniting fire-damp will always fire gaseous inflammable mixtures, but that it is possible to produce binary explosives in which the temperature of detonation is sufficiently reduced to be safe.

It is pointed out that, although the temperature of ignition of marsh gas is $650^{\circ} C.$, the ignition is greatly retarded by admixture with another gas, such as air or even oxygen; the retardation amounting to 12 seconds even if the temperature of the whole volume of gas is at 650° , whilst at lower temperatures it is still longer. It is for this reason that the immense temperature developed by an explosion does not ignite fire-damp, for this temperature is reduced with such great rapidity, some thousandths of a second, that there is not time to ignite mixtures of fire-damp unless the initial temperature is sufficiently great, according to the observations of the present investigators about 2200° or over.

It is interesting to note that explosions not igniting fire-damp will ignite mixtures of coal-gas and air, these having a lower ignition point; and explosions igniting neither marsh-gas and air, nor coal-gas

and air, may ignite a mixture of hydrogen and air. The heat generated by explosives is next studied, and methods and formulae are given for its calculation.* Calorimetric experiments with various explosives freely suspended in the air yielded results, some of which are tabulated below.

	Weight of Cart- ridge. Grms.	Fulminate in De- tonator. Grms.	Increase in Pres- sure after Ex- plosion. Me- tres of Water.	Heat in Cals. for 100 grms. of Explosives calculated.	
				From the Increased Pressure.	From Theoretical Data.
Dynamite.....	50	1.5	0.83	97.0	97.2
Military gun-cotton (205 cc. of N_2O_2)	50	"	0.72	88.0	104.0
Mining gun-cotton (193 cc. of N_2O_2)	50	"	1.48	172.0	103.0
Blasting gelatine (Paulilles),	40	"	0.56	80.2	153.5
" "	50	"	0.69	80.6	"
Bellite	50	"	0.28	32.7	100.2†
"	50	3.0	0.34	39.8	"
Pyroxylin powder (Moulin- Blanc).....	50	1.5	0.60	70.0	82 dissoci. of $BaCO_3$.
" "	65	"	0.61	54.7	" "
58 gun-cotton + 42 barium nitrate	50	"	0.70	82.0	81 dissoci. of $BaCO_3$.
20 gun-cotton (173 cc. of N_2O_2) + 80 ammonium nitrate.....	50	"	0.15	17.5	80
25 " + 75 "	50	3.0	0.41	48.0	91
35 " + 65 "	50	1.5	0.43	50.0	102
60 " + 40 "	30	"	0.35	68.1	96
80 " + 20 "	30	"	0.63	123.0	82
90 " + 10 "	30	"	0.94	183.0	76
20 dynamite + 80 ammo- nium nitrate.....	50	"	0.225	26.4	50
67 dynamite + 33 ammo- nium alum.....	50	"	0.445	52.0	53‡
50 dynamite + 50 ammo- nium chloride	50	"	0.42	49.2	10||
60 " + 40 "	50	"	0.44	51.5	35
67 " + 33 "	50	"	0.53	62.0	49

* Proc. Nav. Inst. 15, 306; 1889.

† Calculated for the proportions $175C_6H_4(NO_2)_2 + 825NH_4NO_3$.

‡ Allowing for complete combustion of the dynamite and simple dehydration of the alum.

|| Complete combustion of dynamite, and decomposition of ammonium chloride into $HCl + N + H_3$.

Wherever the heats found coincide with the theoretical, complete detonation has ensued, and therefore these results confirm and explain the behavior of the various explosives already noticed. In explanation of the apparent anomaly of the lower nitrated gun-cottons giving higher temperatures than the more strongly nitrated ones, it is shown that the proportion of combustible gas in the gaseous mixture produced by the detonation increases as the proportion of nitrogen in the cotton diminishes; therefore the lower nitrated cottons should yield a more inflammable mixture which, by its combustion, would produce a great increase in temperature, and might even account for those temperatures which exceed the theoretical in the above table.

A similar behavior is observed with mixtures of gun-cotton and barium nitrate. A gun-cotton indicating by titration 180 cc. of N_2O_2 always ignites marsh gas, because the temperature of detonation, about 2000° , is increased by the combustion of the inflammable gas produced by the detonation; whereas the pyroxylin powder containing 60 per cent of this gun-cotton, 30 per cent of barium nitrate, and 6 per cent of potassium nitrate ignites marsh gas only exceptionally, owing, it is suggested, to the oxygen supplied to the mixture in the form of nitrates being sufficient to burn enough material so as to dilute the gaseous mixture produced by the detonation and render it non-inflammable; but by adding more barium nitrate, so as to provide enough oxygen to consume all the gas and admitting the subsequent dissociation of the carbonate, the temperature of detonation is raised to 2550° , which is sufficiently high to ignite fire-damp. With regard to force it is shown that the same amount of power may be produced at a lower price by the use of larger quantities of dynamite and ammonium nitrate than by employing smaller quantities of the more expensive dynamite.

Irregularities in explosives, such, for instance, as incomplete detonation, which produces indefinite reactions, are a source of danger, and are more common in mixtures than in simple explosives. These reactions vary under different circumstances, such as the amount of fulminate used for detonation, the temperature of the charge at the time of explosion, etc., therefore an explosive should not be considered safe if, amongst its several modes of detonation in the open air, there be one susceptible of igniting marsh gas. The most suitable substance for reducing the temperature of detonation of an explosive is ammonium nitrate, as other substances, such as sodium carbonate,

or sulphate, or alum, or ammonium chloride, only decompose partially and their effect is uncertain. Mixtures worthy of further consideration are: the pyroxylin powder; gun-cotton (173 cc. N_2O_2) with 80 per cent of ammonium nitrate, giving a force of 7550 grams and a detonating temperature of 1920° ; dynamite, with 80 per cent of ammonium nitrate, $f=6260$ grams, $t=1500^\circ$; bellite, $f=2993$ grams, $t=2186^\circ$; Favier's explosive, $t=2120^\circ$. The last two require to be further experimented with. Ammonium nitrate reduces regularly, as the proportions of it in the mixture increases, both the temperature and power of dynamite and highly nitrated gun-cotton; but with octonitric gun-cotton these reductions do not set in until 70 per cent of nitrate is present. Curves illustrating this behavior are given in the report.

Experiments were now made with the more dangerous explosives confined in tubes of lead or tin, closed below and open at the top. The explosive was placed and rammed in the tube, on a plug of marl or sand 5 to 6 centimetres thick. It was then tamped with clay or sand, or, in some cases, coal-dust to the thickness of 10 to 12 centimetres. Tubes of various thicknesses were used and exploded, as in the previous experiments, in the boiler. The portion of the tubes surrounding the explosive was blown to powder, whilst the upper and lower portions were generally found nearly intact at the bottom of the boiler. The following table of results illustrates the effect of the thickness and quality of the tube on the temperature of explosion.

Explosive.	Description of Tube.		Material.	Effect on Mixture of Marsh-Gas and Air. I = Ignition. N = No ignition.
	Diameter.			
	Internal. mm.	External. mm.		
Dynamite,	27	40	Lead	N.
“	30	40	“	I.
“	30	35	“	I.
“	25	40	Tin	N.
Mining gun-cotton, . . .	32	42	Lead	N.
“ “	30	35	“	N.
Blasting gelatine, . . .	25	40	Tin	I.
Dynamite gelatine, . . .	27	40	Lead	N.
Ammoniacal dynamite, .	25	40	Tin	N.

Other conditions being the same, the safety of the explosive increases with the thickness of the tube, owing, it is assumed, to the

fact that much of the heat of detonation is converted into mechanical force, and so the temperature is reduced below the dangerous limit. Dynamite loses more than one-third of its initial heat of detonation in shattering the tube and distributing the debris. To ascertain the effect of the density of a charge, the explosive was enclosed in a thin glass tube and fixed by wads between the clay plug and tamping in the metal tube so as to leave an annular space between the metal sides of the tube and the exterior of the glass tube. Under these circumstances it was observed that the work done on the tube was greatly diminished, owing, it is suggested, to the expansion of gases within the tube, and instead of one-third, only one-fifth of the initial heat of the detonation of the dynamite was absorbed. The same result is observed with loosely packed explosives; for example, dynamite simply poured into a 32-42 mm. lead tube and tamped, ignited fire-damp, whereas under the same conditions with the dynamite rammed in, no ignition ensued. This shows the importance of ramming and tamping well when using explosives. Altering the shape of the tube simply varies the work imposed on a unit volume of gas, the larger the proportion of surface the greater the imposed work, but does not affect the density of the charge. Further experiments show that dynamite alone or mixed with 80 per cent of ammonium nitrate, or 33 per cent of ammonia alum, or 40 per cent of ammonium chloride; bellite; pyroxylin powder (Moulin-Blanc); and gun-cotton (173 cc. N_2O_2) mixed with even 40 per cent of ammonium nitrate, explode completely when confined in 25-40 mm. tin tubes, bellite even in a 30-35 mm. lead tube; but blasting gelatine requires a stronger tube to ensure its complete detonation.

With regard to modes of igniting the charge, when a fuze (Bickford) is used, care must be taken not to place it in contact with the explosive, for under such circumstances gas and flame may be projected through the tube into the external air, and so produce ignition of the fire-damp. Other objections to the Bickford fuze are the uncertainty of its composition and the danger attached to lighting the exposed end. When electricity is used, preference should be given to currents of low tension, so as to avoid sparking and possible ignition of fire-damp. Detonating cords made of gun-cotton have been found uncertain. Lauer's friction cap has not yet been investigated by the Commission. Various detonators have been examined, and, with the exception of those of Ruggieri and Scola, and ordinary 1.5-gram fulminate caps, they do not ignite mixtures of marsh-gas and

air when exploded by themselves. Strengthened fulminate caps differ from the ordinary ones chiefly in being made of stouter metal and having the fulminate more compressed, and covered by a little metallic plate with a hole in the centre to allow access of fire; the gases from the explosion of these caps have, therefore, more work to do, and lose temperature, and consequently a strengthened 1.5-gram cap, as might be presumed by the above hypothesis, does not ignite a mixture of marsh gas, or even coal-gas and air, but does ignite a mixture of hydrogen and air; a larger charge, however, 5 grams for instance, produces sufficient heat to ignite fire-damp. By imposing more work on the gases of detonation of an ordinary fulminating cap, a similar effect is produced. Thus, by winding fine copper wire closely round the outside of an ordinary 1.5-gram cap, this ceases to ignite fire-damp when detonated.

The conclusions arrived at have already been mentioned above, but special stress is laid on the importance of making the explosive do as much work as possible; and bearing in mind the uncertainty attached to the use of even the safest explosives, and the advisability of avoiding their use in presence of inflammable mixtures of marsh-gas and air, the selection of the safest explosive "ought to be considered as diminishing the danger of explosion considerably, but it ought not to be regarded as suppressing it absolutely."

Binary mixtures of ammonium nitrate with dynamite or gun-cotton or dinitrobenzene are recommended from a point of view of safety, although it is suggested that experiments should be made on the method of manufacture of these mixtures, on their durability, and on their behavior in mines. All the results of the numerous experiments are tabulated, and notes containing interesting theoretical considerations are appended, in which methods of calculating the force and temperature obtainable from explosives are given, and the results of such calculations are also tabulated. An objection to the use of water cartridges is the large bore-holes required.

Subsequent to the drawing up of the above report further experiments were made, using a mixture of coal-gas and air, thus avoiding the expense of the manufacture of marsh gas. The most explosive mixture of coal-gas and air contains 15 to 16 per cent of the former. In the experiments it was more convenient to use a mixture containing 10 per cent; the ignition temperature of this mixture appears to be about 2100° . This was ascertained in the same way as the ignition temperature of marsh-gas and air, namely, by exploding in it

various cartridges of which the temperature of detonation, etc., could be calculated, the cartridge giving the lowest temperature and igniting the mixture being the one selected for fixing roughly the ignition temperature of the mixture. This mixture of gas and air is not much more inflammable than marsh-gas and air; therefore it is considered that it would not be too severe a test to make all explosives destined to be employed in presence of marsh gas satisfy the condition of not igniting such a mixture of coal-gas and air when detonated while freely suspended in it.

In the first report it was suggested that the moisture of the atmosphere aided the explosion of fire-damp, but further experiments have not confirmed this suggestion.

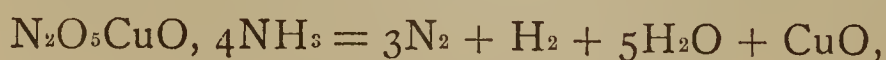
The statements regarding dynamite are not altered in the second report, but as regards gun-cotton it is shown that, although the gases from octonitric cotton burn in the air when the cotton is exploded unconfined, nevertheless when this explosive is confined in a tin tube, 25 mm. internal diameter, 31 mm. external, or thicker, not only does the gas not burn, but also the detonation is incomplete. By testing mixtures of dynamite and ammonium nitrate containing from 90 to 40 per cent of the latter, it is shown that the detonating power increases as this proportion decreases, and complete detonation of the unconfined mixture does not take place until 50 per cent of dynamite is reached; even increasing the amount of fulminate used with the 20 per cent dynamite mixture scarcely improves the extent of detonation. In a 25 mm. by 31 mm. tin tube the condition of affairs is not much better, but in a 25 mm. by 40 mm. tin tube complete detonation of both dynamite and nitrate ensues. The gases evolved from this mixture do not react on one another; the same is the case with mixtures of dynamite and alum, ammonium chloride, etc. It is suggested that in such mixtures the non-explosive constituent, the one absorbing heat on decomposing, is decomposed only slightly, or not at all, during the propagation of the explosive wave, their decomposition only taking place in a closed tube. Various mixtures giving gases which react on one another were examined, such as mixtures of ammonium nitrate with combustible substances, gun-cotton, dinitrobenzene, ammonium picrate, naphthalene tar, heavy coal-oils, colophony, etc. In the open air they behave sometimes as if the explosive wave, excited at one point, exhausted itself before traversing the whole mass of the explosive; at other times, as if the explosive wave passed through the whole mass of the explosive, but stopped

at the decomposition of the explosive constituent or constituents, the gases evolved being dispersed before reacting mutually; therefore the detonation in the open air is incomplete. When, however, the gases are confined, as, for instance, when the explosive is put in a sufficiently strong metal case, then the reaction between the gases takes place, and the effect of a complete detonation is obtained. There are numerous results, tabulated, illustrating these points. Mixtures of about 80 per cent of ammonium nitrate with gun-cotton, or 83 per cent with dinitrobenzene, do not detonate completely either in the air or in thin (25x31 mm.) tubes, but do in 25x40 mm. tubes. Mixtures of ammonium nitrate and picrate in the open air give an effect equal to the decomposition of the nitrate, but in the tube the result is equal to the decomposition of both. With tars, etc., the result is never much above that attributable to the ammonium nitrate.

Experiments were now made with increasing quantities of safety mixtures to test their capability of igniting the inflammable gaseous mixture; the various results are tabulated and discussed. In the following table is given various data relating to the mixtures which proved safe; other mixtures already referred to are either too expensive or inconvenient, or improper as explosives, as far as the present results indicate.

	Force in kilos.	Heat from 1 kilo in cal.	Grms. of Fulminate required for Detonation.
Dynamite (for comparison),	8.490	1.109	...
30 of dynamite, 70 of ammonium nitrate,	6.750	.600	0.50
20 " 80 " "	6.260	.530	0.50
20 of gun-cotton,* 80 of " "	7.610	.810	1.50
15 " " 85 " "	7.000	.700	1.50
12½ of dinitrobenzene, 87.5 "	8.000	1.006	1.50
10 " " 90 " "	6.700	.750	1.50

Other mixtures worthy of consideration are those containing mononitronaphthalene, or naphthalene, and ammonium nitrate, but their behavior is at present uncertain. Finally, attention is called to mixtures of ammonium copper nitrate and ammonium nitrate. The heat of formation of this salt $\text{N}_2\text{O}_5\text{CuO}$, 4NH_3 is for ($\text{N}_6 + \text{H}_{12} + \text{O}_5 + \text{CuO}$) 164.1. The products of decomposition have not been studied, but the mode of disengaging most heat is as follows :



* About octonitric.

disengaging 516 cal. per kilo. When exploded in the air, white fumes of ammonium nitrate and of oxides of nitrogen are evolved; therefore the products are uncertain. Its complete combustion by ammonium nitrate is represented by the following equation:



or proportions of 76 to 24 of nitrate, heat produced per kilo = 655.5 cal., whilst the force = 6.090 kilos, and temperature of detonation 1750°. This was therefore considered as an interesting explosive in connection with safety in fire-damp. In the open air or in tubes the detonation of the salt does not appear complete according to the above equations, either alone or when mixed with ammonium nitrate; in fact, is almost arrested in the open air when the nitrate present is double the copper salt. It is believed it would explode completely in a mine bore-hole; with regard to its safety the results are very satisfactory, even with mixtures containing only 25 per cent of nitrate, but the mixture containing 80 per cent of nitrate is safe in coal-gas, detonating at a temperature of 1300°, with a force of 5500 grams.

In conclusion they point out that safety mixtures of dynamite and ammonium nitrate should not contain less than 80 per cent of the latter. The other mixtures must fulfill the conditions of having a temperature of detonation lower than 2200°, of not yielding combustible gas after complete detonation, of having sufficient force to avoid use of larger quantities of the explosive, of being sufficiently explosive to minimize missfires, of being kept sufficiently long without undergoing change, and they must not be too expensive. Mixtures fulfilling these conditions more or less are those with ammonium nitrate, and (1) a maximum of 75 per cent of ammonium copper nitrate; (2) 6 per cent of naphthalene; (3) 15 per cent of octonitric gun-cotton; (4) 10 per cent of mononitronaphthalene; (5) 10 per cent of dinitrobenzene. They recommend trials of these in mines.

To avoid danger as much as possible, the mixtures should be well mixed, and the smallest proportion of the dangerous substance, consistent with efficiency, should be used.

As safety depends on the instantaneous admixture of the gas of the detonation with the surrounding atmosphere, it is therefore dangerous to blast with a large quantity of explosive in a confined space.—*J. Soc. Chem. Ind.* 8, 415-419; 1889.

H. Lohmann, in *Zeits. f. Berg., Hütten- und Salinwesen* 83; 1889, gives a "Report on Further Experiments with Explosives at the Experimental Level of the König Colliery, near Neunkirchen (Saarbrücken), in Respect to their Behavior with Fire-damp and 'Coal-Dust,'" in which he states that *an explosive* consisting of a mixture of dynamite with 40 per cent of soda crystals gave very good results, both as regards safety from colliery explosions and the production of large coal. Samples of "carbonite" gave better results than before, and the cartridges were better made. Water cartridges—the explosives surrounded with water—gave good results as to safety.

"Ammonia dynamite" consists of 40 per cent of ammonium carbonate, 10 per cent of nitre, and 50 per cent of a mixture of nitroglycerol and kieselguhr, containing sufficient of the latter to make the mass plastic but not too soft. The introduction of ammonium carbonate is less advantageous than the oxalate. A good mixture is 45 per cent of ammonium oxalate, 15 per cent of nitre, and 40 per cent of the kieselguhr dynamite. It seems possible that by some alteration in the composition of ordinary black powder it may be possible to use it in collieries with safety, ammonium oxalate being used in place of carbon.

"Securite" gave bad results as regards safety from explosion. The Rottweil powder works has consequently much altered and greatly improved this explosive.

"Roburite" was used with success in workings which were free from fire-damp. Analysis failed to show the presence of chlorine in the explosive obtained from Witten, although it was supposed that some of this element was present.

As regards risk from explosion, "ammonia dynamite" proved to be very safe; "kieselguhr dynamite" and "gelatine dynamite" were bad and about equally so; "roburite" is better than "gelatine dynamite," but not so good as "ammonia dynamite," although it is possible that this explosive may have been recently still more improved. "Carbonite," the improved "securite," and "soda dynamite" afford great safety. "Gelatine dynamite No. 2" is as good as "No. 1," and Favier's explosive, one sample of which consisted of dinitrobenzene, mononitronaphthalene, ammonium nitrate and nitre, also gave very good results.—*Loc. cit.* 419.

English Patent No. 9164, June 23, 1888, has been granted T. G. Hart for "Improvements in Explosives for Use in Firearms," which

claims a form of gunpowder consisting of compressed potassium chlorate, granulated, and permeated "with a saccharine solution or other suitable hydrocarbon liquid."

Silesit is the name given to an explosive for which Austro-Hungarian Letters Patent No. 2219 were issued November 12, 1887, to Drs. Pietrowicz and Siegert. It consists of potassium chlorate 60 parts, antimony sulphide 10 parts, and sugar 30 parts.

English Patent 13789, Sept. 24, 1888, has been granted T. M. Justice for "An Improved Explosive Compound."

This invention relates to an explosive composed of "a suitable nitrate" coated with a hydrocarbon, such as paraffine or naphthalene, and rendered sensitive to detonation at the desired time by admixture with potassium chlorate.—*Jour. Soc. Chem. Ind.* 8, 818; 1889.

English Patent 11102, July 10, 1889, has been granted W. H. A. Kitchen and J. G. A. Kitchen for "A New Explosive."

This invention relates to a mixture of chlorate of potassium, coal dust, and resin or sulphur.

We have previously noted that when picrate of potash is used in rockets and bombs a curious whistling sound is produced.* U. S. Letters Patent No. 411714, September 24, 1889, have now been granted Antonio del Grande for "Preparing Pyrotechnic Compounds," in which he claims the method of preparing potassium picrate by reacting on a solution of picric acid with magnesium carbonate, and mixing with this an aqueous solution of potassium nitrate, by which potassium picrate is precipitated.

English Patent 13360, Sept. 15, 1888, has been granted T. Chandelon for "Improvements relating to the Manufacture of Explosives," the chief feature of the invention being the use of organic picrates, together with nitrates, or chlorides or both, to form an explosive compound.

Mixtures are described of picrate of benzene, picrate of nitrobenzene, picrate of dinitrobenzene, and picrate of nitronaphthalene with nitrate of ammonia or other nitrates; also of mixtures of the above picrates in which the nitrate has been replaced wholly or partly by a chlorate.

* *Proc. Nav. Inst.* 15, 85, 86; 1889.

H. von Asboth proved the "Presence of Pyridine in Amyl Alcohol," *Chem. Zeit.* **13**, 871-872, by dissolving picric acid in the alcohol, when crystals of what proved to be pyridine picrate crystallized out. These crystals melt at 144.5° , and are decomposed by strong acids or bases with the separation of pyridine. Heated gently, they are partially decomposed; strongly heated, they decompose. Their formula is $C_5H_5NC_6H_2(NO_2)_2OH$.—*J. Soc. Chem. Ind.* **8**, 134; 1889.

English Patent 370, January 10, 1888, has been granted S. H. Emmens for "The Preparation of Certain New Compounds from Picric Acid, and the Manufacture therefrom of Explosives, partly applicable also to Colored Fires."

The crystals deposited, after treatment of picric acid with red fuming nitric acid of sp. gr. 1.52, are called by the inventor "Emmens" acid, and are an ingredient of his explosives.

The liquor remaining after the deposition and removal of these crystals will yield a second crop of similar crystals, and will deposit simultaneously a quantity of lustrous flakes. These flakes, heated in water, separate into two new bodies, one of which enters into solution and forms crystals unlike the above, while the other body fuses and remains below the water undissolved.

These acid crystals and residuum are also used as ingredients of the explosives and a mixture of "Emmens" acid, and these two new bodies are called "Emmens" mixture. Explosives are formed by fusing "Emmens" acid to a nitrate together, or "Emmens" mixture and a nitrate, and such explosives are called "Emmensite." The mixtures have to be exploded by detonation.

English Patent 10722, July 24, 1888, has been granted A. Nobel for "Improvements in Explosive Compounds." This invention relates to the manufacture of an explosive consisting of nitrate of ammonia and picrate of ammonia in the proportion of three parts of the former to one part of the latter.

Gum arabic, dextrin, or an analogous substance is added in the proportion of about $\frac{1}{2}$ per cent of the material, with a view of hardening it.

English Patent 6560, May 2, 1888, has been granted A. Nobel for "Improvements in Explosive Compounds." This invention relates to the treatment of nitrated starch and nitrated dextrine for the production of explosive compounds to be used in place of gunpowder.

For this object nitrated starch or nitrated dextrine is incorporated with nitrocellulose, and both dissolved in a suitable solvent, such as acetone, etc. By means of such solvents, which are afterwards distilled off and recovered, a very perfect incorporation can be brought about.

Other explosive substances or oxidizing agents, such as picrates, chlorates, nitrates, etc., may be incorporated with the aforesaid materials, the quantity of the solvent being so far increased as to allow of a complete and uniform distribution of the substance to be incorporated.

U. S. Letters Patent No. 411127, dated Sept. 17, 1889, have been granted Hudson Maxim, of Pittsfield, Mass., for a "Method of Producing High Explosives."

The object of this invention, as stated, is to prepare a high explosive in a form so that, while retaining all the explosive power of its constituents, it will be in such a compact, solid, and therefore stable condition as will permit it to be readily and safely handled and will adapt it to be projected from ordnance with gunpowder; that is to say, it is the purpose to prepare the explosive so that it may be packed in shells and other projectiles and safely fired from guns as shells charged with ordinary gunpowder are commonly fired.

To this end the invention consists in dissolving gun-cotton or nitrocellulose in a proper solvent which is capable of being evaporated, adding to the dissolved nitrocellulose nitroglycerine, and then evaporating the volatile solvent from the mixture.

In carrying out his invention he first thoroughly dissolves gun-cotton in the solvent, which usually will be a liquid, such as acetone or ethylic acetate, or a mixture of sulphuric ether and alcohol. A sufficient quantity of the solvent will be employed to thoroughly reduce or dissolve all, or practically all, of the gun-cotton. The nitroglycerine will then be added and thoroughly incorporated with the dissolved nitrocellulose. The product thus produced is now to be spread out and the volatile solvent evaporated therefrom, the residue being a comparatively hard, dense, and rigid mass, the components of which are maintained in a stable and safe condition. He claims that this explosive has all the high power of gun-cotton or nitrocellulose and of nitroglycerine, cannot readily be exploded by concussion, and may be worked and shaped for the purpose of charging shells or projectiles. The presence, however, of the nitroglycerine

in the explosive renders it capable of being exploded by ignition or by a detonating charge of fulminate of mercury, or by electricity. The quantity of nitroglycerine, however, is not sufficient to make it susceptible of exploding by any ordinary form of concussion, such as it would be subjected to in handling or in being discharged from a gun with gunpowder.

The quantity of nitroglycerine in the explosive will, of course, depend upon the desired sensitiveness of the compound, and, accordingly, as the explosive contains more or less of nitroglycerine will it be necessary to employ a detonator of less or greater energy. In practice the object will be to add only such quantity of nitroglycerine as will insure the proper instantaneity of explosion.

He states that other solvents may be employed, such as vapors of various liquid solvents or a partially dry solvent; or even a dry solvent may be used, such as camphor; and he therefore does not limit himself to any special form or kind of solvent. So, also, the nitroglycerine may be mixed with a solvent capable of dissolving the nitrocellulose, and the latter be dissolved in conjunction with the nitroglycerine.

Aware that gun-cotton has heretofore been reduced to a very tough, dense, and solid mass by solvents, he does not claim such process, as the explosive thus produced has not the capacity of exploding with the certainty of his explosive, as he states, and that it has not the proper degree of sensitiveness to the detonating charge, and the instantaneity of its explosion depends largely upon the conditions of its confinement. He is also aware that gun-cotton has been dissolved in nitroglycerine, thus producing what is known as "nitrogelatine"; but this is not his process, for the resulting explosive is an unstable jelly-like mass, very susceptible of explosion, while his explosive has all the advantages of those last named products with none of their disadvantages.

He does not claim therein the compound produced by the process described, the same being previously claimed in his application, Serial No. 318670, filed July 25, 1889, but desires to reserve his right to claim said compound.

What he claims as new is:

1. The herein described process of producing high explosives, consisting in dissolving gun-cotton or nitrocellulose in a suitable solvent, adding to the dissolved nitrocellulose nitroglycerine, and then evaporating from the mixture the volatile solvent.

2. The process herein described for manufacturing explosives, which consists in dissolving nitrocellulose in a volatile solvent, combining therewith nitroglycerine, and evaporating the volatile solvent therefrom after the admixture of the nitroglycerine.

Austro-Hungarian Patent No. 2387, November 25, 1887, has been granted D. Johnson for "Gunpowder from Nitrocellulose." For sporting powder the mixture consists of dinitrocellulose 68 parts, barium nitrate 25 parts, potassium nitrate 6 parts, and ultramarine 1 part. These are mixed with water, corned and dried, and they are then treated with a mixture of camphor 10 parts and benzene 50 parts, when they are warmed to about 100° C., to convert the whole.

For military powder the proportions are dinitrocellulose 35 parts, barium nitrate 60 parts, and charcoal or lampblack 5 parts.

English Patent No. 14027, September 29, 1888, has been granted C. O. Sundholm for "Improvements in the Manufacture of Dynamite." The object of this invention is to render dynamite not liable to injury or deterioration by water or moisture, and even capable of acting effectively whilst immersed in water. The invention consists in employing as the absorbent of the nitroglycerine the substance obtained by carbonizing without access of air, a siliceous earth naturally containing organic or carbonaceous matter.

According to the *Journal Chemical Industry* **II**, 350-352, Romite, which is the invention of a Swede (Sjöberg), is prepared, according to one method, by treating 10 parts of ammonium nitrate and 7 parts of potassium chlorate with a solution of 1 part naphthalene in 2 parts of rectified paraffine oil. Among the advantages claimed for romite is included safety in manufacture, transport and use, but the writer of this article calls attention to the widely known fact that chlorate compounds constitute unsafe and unstable explosives, and refers to the spontaneous ignition of some romite whilst being conveyed from Sweden to Germany for experimental purposes, under the superintendence of the inventor himself.

English Patent 7497, May 22, 1888, has been granted H. J. Allison for "Improvement in Explosive Compounds," the object of which is the production of a blasting powder, to consist of a mixture of ordinary granulated black blasting powder with nitroglycerol, which shall preserve the granular form and structure of the former and not be

reduced to a pasty, sticky or deliquated mass during mixing. This is effected by mixing starch paste with the materials of the black blasting powder (charcoal and a nitrate), when on drying and granulating this powder possesses a cellular or honeycombed structure, and readily absorbs nitroglycerol while retaining its full granular form.

A Swedish engineer, J. W. Skoglund, has invented a new explosive which he calls Grakrut. According to the official reports this gray powder has been used with 25 millimeter as well as with Nordenfelt's machine guns. The former, with 70 per cent of the new powder against 100 per cent (or the usual charge) of ordinary powder, gives 33 per cent greater initial velocity, without the pressure in the gun being increased more than 5 per cent. With 62 per cent (ordinary charge weight) of gray powder, the initial velocity was increased 24 per cent without any perceptible increase in pressure. With a charge of 74 per cent (ordinary charge weight) the initial velocity was increased 40 per cent without the gun being subject to any undue pressure. With regard to the important question of smokelessness, the report states that while with Nordenfelt's machine guns smoke of ordinary powder remains for twenty-five seconds, the gray powder only leaves a transparent steam, which is only visible for five seconds.—*Sci. Am.* 312; 1889.

English Patent 14623, November 11, 1886, amended October 5, 1888, has been granted C. E. Bichel for "Improvements in the Manufacture of Explosive Compounds."

The inventor prepares a "cheap and harmless explosive" by first sulphurizing resin oil or other hydrocarbons, such as wood or coal-tar or their distillates boiling between 120° C. and 200° C.; secondly, mixing the above with nitrates or chlorates. He also employs the above sulphurized hydrocarbons mixed with nitrobenzene, nitrophenol, nitrotoluene, etc., and with explosive nitro-compounds such as nitroglycerol and nitraniline, in order to render these latter more stable.

The sulphurizing is carried out by distilling the hydrocarbons in combination with sulphur, and it is claimed that the compounds resulting from the above treatment "exhibit the peculiarity that they mix readily with nitro-compounds, whilst in the case of the products of distillation not sulphuretted, even when they appear to mix, a subsequent separation takes place which renders the production of a stable product impossible."

English Patent 11751, August 15, 1888, has been granted C. Lamm, the object of the invention being to protect and preserve explosives which contain hygroscopic salts.

In carrying this out, carnauba or other palm wax is employed mixed with Japan wax, naphthalene, paraffine, etc., as a waterproof coating for the explosive when made up into blocks or cartridges.

English Patent 12424, September 13, 1887, has been granted E. D. Müller for "Improvements in Explosive Compounds," in which the patentee proposes, in order to cool the explosive gas mixtures, to mix various explosives, such as nitroglycerine, with 15-65 per cent of salts containing more than 5 molecules of water of crystallization, preferably soda crystals, the alums, the sulphates, etc. of sodium. These mixtures are formed into cartridges, and at the explosion, the water being converted into steam, cools the gases down to such an extent that an absolute security against the ignition of the explosive gases is obtained. For warm climates magnesium sulphate is preferable to soda crystals or Glauber salt, and different mixtures and salts are selected according to the advantages they offer in special cases.

English Patent 16920, December 8, 1887, has been granted A. Nobel for "An Improved Explosive Compound." The inventor finds that ammonio-nitrate of copper ($4\text{NH}_3\text{Cu}(\text{NO}_3)_2$) possesses explosive properties, and although it cannot be fired by a spark or Bickford fuze, it develops great energy when detonated.

The ammonio-nitrate of copper is not sensitive to concussion. It is claimed that a very short flame of comparatively low temperature is emitted on detonation, not capable of igniting fire-damp under conditions where gunpowder or dynamite would cause it to explode.

It can be used for propelling projectiles after it has been granulated in the same manner as gunpowder is granulated, but has to be fired by a special primer of gunpowder. In filling cartridges for firearms with granulated ammonio-nitrate of copper, the gunpowder primer is so arranged as to be fired directly by the cap, and then the charging is completed as with ordinary gunpowder.

For use in mines it is simply filled into ordinary paper cartridges and fired by a detonator.

English Patent 5061, April 5, 1888, has been granted H. Müller for "Safety Fuze and Igniting Apparatus for Setting Fire to Explo-

sive Charges without Danger from the Presence of Fire-damp," which is effected by means of an envelope of wire, gauze, or similar material fixed on to the tube in a special way.

English Patent 5624, April 16, 1888, has been granted C. A. McEvoy for "Improvements in Fuzes," the object being to form a fuze that will be ignited by immersion in water. This is effected by means of sodium or potassium, or a mixture of both, suitably attached to the fuze.

U. S. Letters Patent No. 414662, November 5, 1889, have been granted Franz L. and Hans Firmann for a "Percussion-Fuze for Blasting." This invention relates to fuzes for blasting and like purposes (such as the firing of cannon) wherein the primer or explosive is exploded by being struck by a hammer.

It provides a percussion fuze which can be safely transported, handled and used. The hammer is normally partly retracted, being so held against the tension of its spring by a safety stop which prevents it moving forward far enough to reach the primer. When the pull-wire is pulled the hammer is drawn fully back, the spring fully compressed, and on increasing the pull the wire is disconnected, so that the hammer is released and flies forward against the primer.

U. S. Patent No. 408096, July 30, 1889, has been granted W. H. Frazer for a "Cap for Fuzes," the cap being made of rubber partially vulcanized, but yet sufficiently flexible to be slipped over the end of a fuze. The inventor seeks by this means to avoid the danger which attends the fixing of the ordinary metallic blasting cap on the leading fuze by the usual method of crimping.

In the "Report of Committee of the Society for the Protection of the Interests of Chemical Industry in Germany," it was proposed, on behalf of the percussion-cap manufacturers, that *denaturized spirit* be mixed with 0.025 per cent bone-oil or 0.5 per cent oil of turpentine, and, in any case, with 0.025 per cent pyridine bases, for the production of fulminating mercury, to the exclusion of wood spirit, which lowers the yield and deteriorates the quality of the product. According to the proposal, the most suitable substance to use in the case of the fulminating mercury manufacture would be the ethereal distillate, which forms a by-product in the manufacture of fulminating silver, as the presence of bone-oil and oil of turpentine gives rise to an undesirable coloration in the manufactured article.—*Chem. Zeit.* **12**, 249.

In a "Note on a Plan for a Nitrogen Iodide Photometer," M. G. Lion proposes, in the *Compt. rend.* **109**, 653-654; 1889, to follow the suggestion of M. Guyard,* and use the property of nitrogen iodide of being decomposed by a ray of light, as means of measuring the photometric powers of different sources. The novelty of his plan consists in using two burettes, each of which contains the reagent, and which are connected together by a capillary tube containing an index of mercury. Each separate beam of light falls on one of the burettes, and any difference in intensity causes a difference in rate of evolution of the nitrogen, which therefore causes a displacement of the mercurial index.

The *Am. Chem. Jour.* **10**, 1888, contains a note by Dr. J. W. Mallet upon the "Influence of Light upon the Explosion of Nitrogen Iodide,"† stating that the instances of explosion of nitrogen iodide, when *under water*, which he has previously described‡ (*Am. Chem. Jour.* **1**, 4-9; 1879), took place when the direct rays of the sun fell upon the explosive, though the explosion was precipitated by friction or concussion. There were but two cases of such explosions, and, as the result of his experience, Mallet finds that under ordinary circumstances nitrogen iodide, while wet, exhibits no extraordinary sensitiveness, and may be safely worked with, only becoming highly dangerous on drying.

C. F. Cross and E. J. Bevan have examined the "Acetyl Derivatives of Cellulose" produced by the method of Franchimont, *Compt. rend.* **92**, 1053, and from the experimental data which they cite, the soluble product of the original reaction appears to be a pentacetyl cellulose. The formation of such a derivative would, of course, have a very important bearing on the constitution of cellulose, and hence the writers reserve any more positive statement regarding the composition of the product until their investigation has been more extended.

Erwig and Koenigs (*Ber. Berl.* 1464 & 2207; 1889), have, however, obtained a pentacetyl dextrose by using this same method.—*Chem. News* **60**, 163; 1889.

C. E. Guignet states, in the *Compt. rend.* **108**, 1258-1259; 1889, that "Colloidal Cellulose" may be produced by immersing in

* *Proc. Nav. Inst.* **14**, 441; 1888. † *Ibid.* **14**, 441; 1888. ‡ **13**, 424; 1887.

sulphuric acid of 50° B. filter paper which has been previously treated with HCl and HF, or carded cotton of the finest quality which has been thoroughly dried, care being taken to avoid a rise in temperature while the cellulose is immersed in the acid bath. The cellulose forms a transparent, gelatinous mass, which is not affected by contact with a large excess of acid, but is rapidly converted into dextrine at 100°. When the acid has been completely removed by washing (which is most thoroughly done by finishing with alcohol and drying at the lowest possible temperature), the colloidal cellulose dissolves in pure water, forming a slightly milky solution which is readily filtered, deposits no precipitate even after several hours, and is not affected by boiling. If immersed in sulphuric acid of 60° for a short time, or in acid of 55° for a longer time, it becomes insoluble in water. When treated with nitric acid it forms nitrocellulose in the same way as ordinary cellulose, and becomes slightly less transparent. The author regards parchment paper as a cellular tissue, the pores of which are filled with colloidal cellulose.

English Letters Patent No. 16330, November 28, 1887, have been granted C. Stokes for "Improvement in the Manufacture of Non-inflammable Celluloid Matters," which consist in incorporating a quantity of a metallic salt, such as protochloride of tin dissolved in alcohol, ether, or other suitable solvent, with the celluloid or similar substance made from nitrocellulose.

The appearance of a paper by Mr. V. H. Veley upon one aspect of the subject affords C. F. Cross and E. J. Bevan an opportunity for placing on record some experimental results which have accumulated regarding the "Conditions of Action of Nitric Acid" (*Chem. News* 60, 13-14; 1889). They have already cited in *Watt's Dict., New Ed.*, Art. Cellulose, their observation that the presence of urea arrests the specific action of nitric acid upon the liquefied cellulose, changing it into one of simple hydrolysis; and they give here the experimental results upon which this observation was founded, together with subsequent ones, which go to show that with the graduated increase of urea there is a gradual departure from the characteristic action of the pure acid, and the results are so very evident to the senses as to make a very striking lecture demonstration.

These results led them to extend the investigation of the influence of urea—*i. e.* of the elimination of nitrous acid—to other actions of nitric acid, taking first metallic copper, when the solvent action of

the nitric acid was almost completely arrested, and these with similar experiments afforded sufficient evidence that the interaction of nitric acid and the metals is another instance of dependence upon the *tertium quid*, which in this case could scarcely be other than nitrous acid.

As the extension of this investigation to the action of mixtures of $\text{HNO}_3 + \text{H}_2\text{SO}_4$ promised to throw further light on the method of formation and constitution of the explosive derivatives of the celluloses and compound celluloses, a series of comparative nitrations of both cotton and jute fiber were made with and without the addition of urea to the acid mixture, and the evidence as to its influence on the reaction was uniformly negative, a result which strengthens the view that the derivatives in question are alcoholic nitrates. When, on the other hand, the formation of a nitro-derivative is involved, the presence of urea may have a very important influence, as shown by Dr. Perkins, Jr., in a recent note on the "Nitration of Anthracene in Presence of Urea" (*Chem. Soc.*), where this modification of conditions proved sufficient to determine a simple substitution in the carbon nucleus.

Frederick J. Smith having to deal with electrolytic gas in a research on explosions in tubes, and believing that some error would be introduced by the use of rubber tubes as usually employed, has devised a flexible tube which seems almost wholly free from the disadvantages of the diffusion of some gases through rubber.

A length of small rubber tube is drawn through another tube of equal length but of greater diameter; each end is furnished with a small length of glass tube fitting the smaller tube; one end is bound off with cord, then the space between the inner and outer tube is filled with water or any liquid required; the other end is then bound off. By this means a "Water-Jacketed Flexible Tube" is easily constructed.—*Chem. News* 60, 187; 1889.

W. Michelson contributes to the *Ann. Phys. Chem.* 37, 1-24; 1889, a paper on the "Normal Velocity of Inflammation in Explosive Gaseous Mixtures," in which, after reviewing the work of Davy, Bunsen, Schlösing and Mondésir, Berthelot and Vieille, and of Mallard and Le Chatelier, many of which have been resumed in these Notes, he gives the data obtained from a large number of experiments with mixtures of illuminating gas, hydrogen, carbon monoxide and methane with air, and with oxygen, and the mathe-

matical and graphical discussion of the same. The paper is accompanied by numerous tables, illustrations of apparatus used, and photographs of the flames produced.

M. Neyreneuf contributes to *Ann. Chem. Phys.* **17**, [6], 351-377; 1889, a paper entitled "Researches on the Chemical Harmonica," or singing flame, that contains some fine illustrations of the beautiful figures developed by explosions of gaseous mixtures when burnt in this way.

Berthelot and Petit give in the *Ann. Chim. Phys.* **17** [6], 80-106; 1889, the results of their determinations of the "Heats of Combustion of Carbon in its Different States: Diamond, Graphite and Amorphous," from which we extract the following tabular summary, in which the results obtained by Berthelot and Petit are compared with the famous ones of Favre and Silbermann:

Author.	State of Carbon Ash-free.	Gram-units of Heat per gram.	Kilogram-units of Heat per molugrams.
B. & P.	Amorphous (wood charcoal), .	8137.4 cal.	+ 97.65 Cal.
F. & S.	" " " " " " " " " "	8080. "	+ 96.96 "
B. & P.	Graphite,	7901.2 "	+ 94.81 "
F. & S.	" " " " " " " " " "	{ 7796. "	+ 93.55 "
		{ 7762. "	+ 93.14 "
B. & P.	Diamond (Cape),	7859. "	+ 94.31 "
B. & P.	" (Bort),	7860.9 "	+ 94.34 "
F. & S.	" " " " " " " " " "	{ 7770.* "	+ 93.24 "
		{ 7878. "	

In the same volume of the same journal the same authors give on pages 107-140 the results of their determinations of the "Heats of Combustion and Formation of the Nitriles," from which we extract the following tabular summary:

Heats of Combustion.

Name of Compound.	Formula.	State.	Kilogram-units of Heat per molugrams.
Formonitrile, . .	H.CN	liquid.	+ 152.3 Cal.
Acetonitrile, . .	CH ₃ .CN	"	+ 291.6 "
Propionitrile, . .	C ₂ H ₅ .CN	"	+ 446.7 "
Benzonitrile, . .	C ₆ H ₅ .CN	"	+ 865.9 "
Benzyl cyanide, .	C ₆ H ₅ .CH ₂ .CN	"	+ 1023.8 "
Oxalic nitrile, . .	Cn.CN	gaseous.	+ 262.5 "
Malonic " . .	CH ₂ .Cn.CN	solid.	+ 395.1 "
Succinic " . .	C ₂ H ₄ .Cn.CN	"	+ 546.1 "
Glutaric " . .	C ₃ H ₆ .Cn.CN	liquid.	+ 699.8 "

* Number preferred by Favre and Silbermann.

*Heat of Formation from their Elements.**

Name of Compound.	Kilogram-units of Heat per molugrams.
Formonitrile,	+ 23.5 Cal.
Acetonitrile,	+ 0.5 "
Propionitrile,	+ 8.7 "
Benzonitrile,	— 33.1 "
Orthotolunitrile,†	— 34.8 "
Benzyl cyanide,	— 27.9 "
Oxalic nitrile,	— 73.9 "
Malonic nitrile,	— 43.2 "
Succinic nitrile,	— 32.0 "
Glutaric nitrile,	— 22.8 "

The signs and numbers in the above table differ somewhat from those in Berthelot and Petit's final table, but agree with those given under each experiment.

F. Stohmann, C. Kleber, and H. Langbein, *J. pr. Chem.* [2], 40, 77-95, have determined the "Heat of Combustion" of:

	Heat of Combustion. Calories.	Heat of Formation. Calories.
Durene, $C_{10}H_{14}$,	1393.9	+ 29.1
Pentamethylbenzene, $C_{11}H_{16}$,	1554.1	+ 31.9
Hexamethylbenzene, $C_{12}H_{18}$,	1712.2	+ 36.8
Diphenyl, $C_{12}H_{10}$,	1494.3	— 19.8
Naphthalene, $C_{10}H_8$,	1233.6	— 17.6
Anthracene, $C_{14}H_{10}$,	1694.3	— 33.3
Phenanthrene, $C_{14}H_{10}$,	1693.5	— 32.5

The following conclusions may be drawn from these numbers:

(1). The heat of combustion of the solid homologue of benzene increases, on an average, 155.1 cal. for the addition of each methyl-group.

(2). The substitution of the phenyl-group for hydrogen in benzene, to form diphenyl, increases the heat of combustion by 717.0 cal.

(3). The displacement of a hydrogen atom in the hydrogen molecule by the phenyl-group makes the heat of combustion of the benzene molecule thus formed 718.5 cal. higher than that of the hydrogen molecule.

(4). The formation of diphenyl from benzene, with separation of

* Carbon supposed in state of diamond = + 94.3 cal. † $CH_3.C_6H_4.CN$.

two atoms of hydrogen, takes place without any apparent thermal effect.

(5). The thermal values of anthracene and phenanthrene are practically identical.

(6). The conversion of benzene into naphthalene and naphthalene into anthracene raises the heat of combustion some 458 cal. in each case.—*J. Chem. Soc.* 56, 1042; 1889.

Berthelot and P. Petit have examined the "Thermo-chemical Relations of the Isomeric Nitro-camphors," *Compt. rend.* 109, 92–95; 1889, using for this purpose specimens obtained by MM. Heller and Cazeneuve in their study of these bodies. The previous researches of Berthelot have shown that camphor belongs to a special class of aldehydes characterized by the property of combining either with the elements of water to form acids, or with a quantity of oxygen three times as great as for ordinary aldehydes which give rise to bibasic acids with peculiar properties. These derivatives may be represented by diamylenic acid which belongs to the fat acid series, on the one hand, and cymenic acid, which belongs to the aromatic series on the other. The camphenic series thus forms the connecting link by which we pass from the fat acid to the aromatic series. It is quite to be expected then that there should be two nitro-derivatives one of which should be allied to nitro-ethane, and which Berthelot styles *α-camphor nitrate*, and a second which should possess a phenylic function and which he styles *phenol nitro-camphor*.

For the first of these, *α-camphor nitrate*, which has the formula $C_{10}H_{15}NO_3$, these chemists have found the heat of formation from its elements to be + 89.1 cal., and from camphor (solid) and nitric acid (liquid) + 7.3 cal. This last number is of precisely the same order as the heats of formation of the nitric esters, that of ethyl nitrate being + 6.2 cal. and of nitroglycerine + 4.7 cal. $\times 3$. Hence it is not surprising that these chemists should have found that this camphor nitrate detonated immediately when projected in fine drops into a red-hot tube, and that the superheated vapor detonated also.

The phenol nitro-camphor, forms a hydrate of the formula $C_{10}H_{15}NO_3.H_2O$, and this body gave for the heat of formation of the anhydride from its elements + 125.2 cal., and from camphor (solid) and nitric acid (liquid) + 43.4 cal. The last number is very much larger than that for its isomer, and it is related to that of the nitro-derivatives of the aromatic series, which is about 36 to 38 cal. It is

quite to be expected that this nitro-camphor would be less explosive than the former, and the experiments verified this expectation, for when projected in drops into a red-hot tube it was destroyed with carbonization, but without detonation, and the same proved true of the superheated vapor.

In discussing the state of "Unstable Equilibrium of the Atoms," *Zeit. physikal. Chem.* **3**, 145-158, E. Pringsheim says that in substances which readily undergo sudden decomposition or isomeric change the atoms are supposed to be in unstable equilibrium, and he points out that the heat developed in such cases is usually very large, and much greater than the energy required to effect the decomposition; hence, if partial dissociation, in the sense of the Clausius hypothesis, is brought about by sudden raising of the temperature or some other disturbance, the heat generated serves to continue and complete the decomposition.—*Jour. Chem. Soc.* (Abstr.), **672**; 1889.

P. Cazeneuve, *Compt. rend.* **108**, 857-859; 1889, has effected the "Reduction of Nitro-camphor to Nitroso-camphor" by boiling 300 grams of chloronitro-camphor and 1500 grams of 93° alcohol for about one-half hour with a copper-zinc couple made the action of a solution of 100 grams of copper sulphate on 600 grams of granulated zinc. The filtrate was then distilled to dryness, the cupric oxychloride removed by treatment with warm dilute chlorhydric acid, and the residue recrystallized from alcohol, when the nitroso-camphor was obtained as a white, crystalline solid, insoluble in water, slightly soluble in cold alcohol, but more soluble in boiling alcohol or benzene. It alters when exposed to light, becomes greenish, and gives off nitrogen oxides. It is neutral to litmus and orange III, but acid to phenolphthalein. It does not melt before decomposing, but at 180° it suddenly becomes green, entumescs, and evolves nitrogen oxides. If thrown on red-hot platinum it detonates.

A. Behal, in a paper entitled the "Conversion of Methylbenzylidene Chloride into Triphenylbenzene," *Bull. Soc. Chim.* **50**, 635-638, states that the liquid product of the action of phosphorus pentachloride on acetophenone, after standing for eight months, exploded spontaneously, and crystals of triphenylbenzene were formed at the same time. On investigating this phenomenon, the author found

that water determined the decomposition of the original substance into hydrogen chloride, monochlorcinnamene, and acetophone, the latter compound having resulted from the action of water on the previously formed monochlorcinnamene, and that if the latter body were saturated with dry hydrogen chloride and heated in a sealed vessel at 40° , it exploded, with formation of triphenylbenzene crystals.—*J. Chem. Soc.* **56**, 998; 1889.

In the study of the "Pyrimidines" (Metadiazines), *Ber.* **22**, 1612–1635; 1889, A. Perines has obtained the dichloronitroethylpyrimidines, $C_7H_7N_2Cl_2NO_2$, in the form of a yellow powder which explodes when heated.

Among the bodies obtained by D. S. Hector in his study of the "Action of Hydrogen Peroxide on Phenylthiocarbonide," *Ber. Berl.* **22**, 1176–1180; 1889, is the silver nitrate derivative of dianilidoorthodiazothiole, $C_{14}H_{12}N_4S.AgNO_3 + H_2O$, which decomposes on exposure to light and explodes when heated; and the nitroso-derivative, $C_{14}H_{11}N_4S.NO$, which turns yellow when dried and explodes when heated.

Among the derivatives of "Orthonitrosulphanilic Acid" obtained by J. Z. Lerch, *Chem. Centr.* **286**; 1889; *Listy Chem.* **13**, 85–89, is the orthonitroazobenzeneparasulphonic acid, which crystallizes in long yellow pyramids that explode when heated.—*J. Chem. Soc.* 880; 1889.

In describing the "Action of Hydriodic Acid on Allyl Iodide," *Bull. Soc. Chim.* **50**, 449–451, H. Malbot says when hydrogen iodide is passed into allyl iodide some propylene is liberated and great heat is evolved, eventually causing the propylene iodide which has accumulated to decompose with explosion. The explosive substance may be destroyed almost as soon as formed by alternately passing the current of acid and then warming the liquid; an explosion is thus prevented, but at the same time the conversion of propylene iodide into isopropyl iodide is hindered, and nothing is obtained but propylene gas and a residue of iodine, with a little carbonaceous matter. If the allyl iodide is mixed with isopropyl iodide, the reaction is much less violent, but still little if any allyl iodide is converted into isopropyl iodide. If, however, the mixture is cooled with ice and salt, the conversion is nearly complete.—*Jour. Chem. Soc.* **56**, 766; 1889.

K. Buchka states (*Berl. Ber.* **22**, 829-833 ; 1889) that the "Preparation of Metanitrotoluene" can best be effected by dissolving pure metanitroparatoluidene, prepared by Gattermann's method, in alcohol (3 parts) and concentrated sulphuric acid (3 parts), and adding drop by drop to the cold solution a saturated aqueous solution of sodium nitrite which contains rather more than the calculated quantity of the nitrite. As soon as all of this is added the solution is kept for some time, then carefully warmed until the evolution of nitrogen has ceased and the liquid has assumed a dark brown color. The alcohol is evaporated, the product distilled with steam as long as oil passes over, and the metanitrotoluene extracted with ether. The product thus obtained distills entirely between 228° and 231° , and solidifies when cooled, melting again at 16° . The yield is from 66-84 per cent of the theory, though one experiment gave 90 per cent.

As the result of the "Action of Methyl Diazoacetate on Ethereal Salts of Unsaturated Acids," E. Buchner has obtained the methyl acetylenedicarboxylodiazacetate, $C_3HN_2(COOMe)_3$, and he has prepared from this ester the acetylenedicarboxylodiazacetic acid, $C_6H_4N_2O_6$. The silver salt of this acid, he finds, explodes slightly when heated, yielding an oil which is probably either $C_3H_4N_2$ or $C_6H_8N_4$.—*Berl. Ber.* **22**, 842-847 ; 1889.

"Diamide Hydrate and Other Salts" have been obtained by Curtius and Jay, who have continued their researches upon the compound diamide N_2H_4 , which was isolated by the former chemist in 1887. They have obtained the hydrate by distilling diamide hydrochloride with caustic lime in a silver retort, and they find it to be a fuming, corrosive liquid, with a strongly alkaline reaction and a taste like ammonia. It appears to be the strongest reducing agent known, and when dropped on mercuric oxide it explodes violently. The study of the salts shows that when any salt of diamide is mixed with a nitrite, free nitrogen is evolved almost explosively.—*Berl. Ber.* **22**, 134 (*Ref.*); 1889; *J. prk. Chem.* **39**, 27, 107.

From a brief but interesting notice of the life of Dr. J. Peter Griess, *J. Soc. Chem. Ind.* **7**, 612-613 ; 1888, we learn that he discovered the first one of the diazo-compounds (that curious group of explosive bodies) in 1858. His work on the azo and diazo bodies was continued from that time up nearly to the day of his death, and may be regarded as classic.

In his study of the "Nitroso-compounds of Ruthenium,"* *Compt. rend.* **108**, 854-857; 1889, A. Joly finds that when brown ruthenium sesquichloride is treated with large excess of nitric acid it yields a red nitrate, and when this compound is treated with successive quantities of hydrochloric acid and boiled for a long time, it yields a pale crimson solution of a chloride which, when evaporated at 120° , leaves a brick-red crystalline mass of the composition $\text{RuCl}_3\text{NO} + \text{H}_2\text{O}$. When heated at 440° in carbon dioxide or in a vacuum, this salt decomposes rapidly with evolution of oxides of nitrogen, and leaving a residue of ruthenium sesquichloride and dioxide.

Solutions of the nitroso-sesquichloride or of the double alkaline salts are not precipitated by alkalies in the cold, but if the solutions are mixed with sufficient alkaline hydroxide or carbonate to combine with three atoms of chlorine, and are then boiled, a pale brown gelatinous precipitate is formed and the supernatant liquid is neutral. After drying at 150° it forms a black mass with a vitreous lustre, which has the composition $\text{Ru}_2\text{O}_3(\text{NO})_2 + 2\text{H}_2\text{O}$. This body is not decomposed by heat at temperatures below 300° , but at 360° it slowly decomposes in a current of carbon dioxide, yielding black graphitoidal oxide, Ru_4O_9 , and above 440° it decomposes explosively with incandescence and evolution of oxides of nitrogen.

H. N. Warren, in treating of "Magnesium as a Reagent," states that, as a reagent in the dry way, magnesium reduces all metals with the exception of the alkalies and alkaline earths, and may possibly aid in the decomposition of the latter, provided a suitable combination of the same could be obtained.

An exception to reduction in this line, however, may be mentioned in the powerful manner in which it attracts molybdic anhydride when fused with the same, the combination being so intense as to be accompanied with loud detonations.—*Chem. News* **60**, 187-188; 1889.

In discussing the "Formation of Deposits of Nitrates," A. Müntz and A. Marcano (*Compt. rend.* **108**, 900-902; 1889) have previously attributed the formation of the deposits of nitrates in South America to the enormous deposits of the excrements of birds, bats, etc., which occur in the immense caverns in the Cordilleras (Abstr. 1885, 1042). They now state that the formation of deposits of nitrates can, in fact, actually be watched.

* *Proc. Nav. Inst.* **15**, 92; 1889.

In many large caverns there are no remains of birds, but the soil is charged with nitrates and is found to contain enormous quantities of the bones of mammals. These bones are very friable, and consist of calcium phosphate, with very small quantities of organic matter. Calcium carbonate is absent, and has, indeed, been converted into calcium nitrate, which is found in the earth by which the bones are surrounded. Bone caverns are numerous in Venezuela, not only in the littoral mountains, but also in the flanks of the Cordillera of the Andes. In some cases the deposit exceeds 10 metres in thickness, and the earth is highly charged with the nitric ferment. The quantity of calcium nitrate present varies from 4 to 30 per cent, and the quantity of calcium phosphate from 5 to 60 per cent. These observations confirm their previous conclusions as to the origin of the nitrates.

According to the *Sci. Am.*, July 20, 1889, a family in Haverhill, Mass., were recently seated about an open grate, in the parlor, in which a fire was burning, when an explosion took place which broke a window screen and a pane of glass in a window some feet away and filled the room with smoke, while the report was so loud as to be heard at quite a distance. Examination showed that an ornamental tube, about one inch in diameter, which arched the fire-place was broken, and that the explosion had been caused by the action of the heat upon resin with which the tube had been filled. It is the custom of the trade to fill tubes which are to be bent with resin, so as to prevent them from collapsing during the operation, but it is also the custom to melt the resin and pour it out after the bending is completed. Evidently this had been neglected in this case.

The Boston *Herald*, May 26, 1889, says that those who use the flash lamp in instantaneous photography should be sure and buy the pure magnesium flash powder, as the article commonly known as "flash powder" is a composition containing picric acid, a highly explosive substance. This mixture was harmless before the flash lamp was invented, but in that species of lamp where an air-bulb is used, there is apt to be a suction after the flash which will draw back the flame into the reservoir containing the powder. Several bad accidents have happened to amateurs through neglect to use the pure magnesium powder.

A flash powder which gives a yellow light for use in orthochro-

matic photography is made from one part of metallic magnesium and five to seven parts of sodium nitrate.

The following books are announced :

“L’artillerie actuelle en France et à l’étranger. Canons, fusils, poudres et projectiles.” Paris, 1889.

“Hand-book of Gunpowder and Gun-cotton.” Wardell, London, 1888.

“Vorschrift über die Versendung von Sprengstoffen und Munitions-gegenständen der Militär- und Marineverwaltung auf Landwegen und auf Schiffen (Sprengstoff-Versendungsvorschrift) nebst militärischen Ausführungsbestimmungen.” Berlin, 1889.

“Anleitung zum Zünden von Bohrlochladungen durch Friction u. s. w.” Von Johann Lauer. Vienna, 1887.

“Anleitung zur Bestimmung der Bohrloch-Ladungen für Sprengungen in Schlagwetter führenden Gruben.” Von Johann Lauer, Vienna, 1887.

“Lauer’s Vorschläge zur Verhinderung von Explosionen u. s. w.” Von Ed. F. Csánk, Vienna, 1887.

“J. Lauer’s Frictionszündmethode.” Von J. Mayer. Reprinted from Oester. Zeit. Berg- und Hüttenwesen, 1887.

The *Mittheilungen des Artillerie und Genie-Wesens*, Parts 8 and 9, 1889, contains a Bibliography of the Periodical Military and Technical Literature for the first half of the year 1889, in which we find thirty-two titles of articles on explosives, besides a considerable number on the use of high explosive charges in shells.

“Mining Accidents and their Prevention,” by Sir Frederick Abel, with a discussion by some thirty-six experts, to which is appended the laws governing coal-mining in each of the United States and in Great Britain and Germany (431 pp., 1889), is published by the Scientific Publishing Company of New York.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH,
DECEMBER, 1891.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XXIII.

The Fifteenth Annual Report of H. M. Inspectors of Explosives, being for the year 1890, shows that though the rigid system of inspection and supervision of explosives factories and magazines, for which this corps is famous, has been maintained, it has not retarded the growth of this important industry, for during the past five years the number of factories in operation has increased from 108 to 123, while the number of persons employed has increased from 7484 to 9820. Notwithstanding this increase in production, the number of accidents occurring during the manufacture and use or abuse of explosives was 132, resulting in 44 killed and 85 wounded, while the average number of accidents for the past ten years was 137.8, resulting, on the average, in 41.4 killed and 102.6 wounded.

No statistics regarding production are given in these reports. This is very much to be regretted, as they would prove a most valuable criterion by which to measure the value and operation of the Explosives Act. Statistics are, however, given for importations, from which it appears that there was an extraordinary decrease in the amount of dynamite imported in 1890, it being but 371,650 pounds, as against an average yearly importation of 1,000,000 pounds for the past eight years. Part of this was accounted for by the increase in the amount of the gelatine explosives, yet the total of

* As it is proposed to continue these Notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. *Address Torpedo Station, Newport, R. I.*

all nitroglycerine explosives imported was less than for 1889 by over 400,000 pounds. 38,000 pounds of bellite, 9700 pounds of fulminate, and 10,950,000 detonators were also imported.

Dr. Dupre's report shows that in 1890, for the first time, the number of samples of gelatinized preparations examined exceeded those of dynamite, and points out that this increased use is due to these bodies being practically unaffected by water, and capable of being graduated in strength with greater readiness than obtains for dynamite, while in addition their plastic nature renders them more easy of use in bore-holes. These explosives are not free, however, from dangers of their own; dangers which manufacturers have not, as yet, completely overcome. The chief of these is their liability to exude. There is also a greater difficulty in insuring absolute stability under the most trying conditions of temperature and storage. Since the establishment of the manufacture of dynamite on a large scale, no authentic case of its spontaneous ignition is on record; whereas there are several such in regard to gelatinized preparations.

The consumption of dynamite is also being affected by the introduction of ammonite, bellite, roburite, securite, etc., whose greater insensitiveness to percussion and friction gives the advantage of somewhat greater safety in manufacture and use.

The different results obtained by different analysts in applying the "heat test" to blasting gelatine and its class has led to a precise description of the French chalk to be used.

For the assistance of inventors who desire to have explosives examined, a memorandum giving the necessary steps to be taken is printed in this report.

The chapter on accidents by fire or explosion, which is a characteristic and important feature of these most valuable reports, occupies some thirty-seven pages, and as usual includes a summary review of the accidents reported from abroad, as well as those occurring at home. It is noted that in the explosion of 80 tons of gunpowder at the Dupont works, October 7, 1890, a larger quantity was involved than in any previous accidental gunpowder explosion. The accidental explosion next in magnitude was that of Erith in 1864, when 57½ tons of powder exploded. The Louisiana, which was intentionally blown up before Fort Fisher in 1864, contained 200 tons of gunpowder. The author, in commenting on this, is misled by our complicated geographical nomenclature.

Extracts from this record of accidents and of that of experiments will be found later on.

Lt. Willoughby Walke, Second Artillery U. S. A., gives in *Jour. Am. Chem. Soc.* **12**, 256–274; 1890, the results of his “Determination of the Strength of Various High Explosives” by the use of the Quinan pressure gauge,* in which he employed nitroglycerine made by the Naval Torpedo Station method and carefully stored until it was thoroughly “clear,” as the standard. This period of rest of several months was found necessary, as the strength of the explosive varied from day to day until it had “cleared,” after which it remained constant. The results obtained were as follows:

NAME OF EXPLOSIVE.	Diminution in Height of Cylinder in Inches.	Order of Strength.
1. Explosive gelatine made from nitroglycerine after the Vonges process.....	0.585	106.17
2. Hellhoffite.....	0.585	106.17
3. Nitroglycerine (made Nov. 19, 1889, tested Jan. 6, 1890).....	0.551	100.00
4. Nobel's smokeless powder.....	0.509	92.38
5. Nitroglycerine (made Jan. 29, 1890, tested on same day, U. S. N. Torpedo Station process).....	0.509	92.38
6. Explosive gelatine (made from nitroglycerine No. 5),	0.490	88.93
7. Gun-cotton (U. S. N. Torpedo Station, 1889).....	0.458	83.12
8. Gun-cotton (Stowmarket, 1885).....	0.458	83.12
9. Nitroglycerine (made according to the French process and tested on the same day).....	0.451	81.85
10. Gun-cotton (made in Artillery School Laboratory),	0.448	81.31
11. Dynamite No. 1.....	0.448	81.31
12. Dynamite, de Trauzl.....	0.437	79.31
13. Emmensite.....	0.429	77.86
14. Amide powder.....	0.385	69.87
15. Oxonite (picric acid fused before being added)....	0.383	69.51
16. Tonite.....	0.376	68.24
17. Bellite.....	0.362	65.70
18. Oxonite (picric acid not fused).....	0.354	64.24
19. Rack-a-rock.....	0.340	61.71
20. Atlas powder.....	0.333	60.43
21. Ammonia dynamite.....	0.332	60.25
22. Volney's powder No. 1.....	0.322	58.44
23. “ “ 2.....	0.294	53.18
24. Melinite.....	0.280	50.82
25. Silver fulminate.....	0.277	50.27
26. Mercury fulminate	0.275	49.91
27. Mortar powder, Dupont.....	0.155	28.13

* Proc. Nav. Inst. **8**, 663; 1882.

U. S. Letters Patent No. 455,217, June 30, 1891, have been granted Carl Lamm for an invention, the object of which is to provide an explosive less dangerous than nitroglycerine in its manufacture, transportation, and use.

He describes this explosive as being in the nature of a compound consisting of a nitrate (such as nitrate of ammonia, of potassa, of soda, or of baryta) and dinitro-benzine, or dinitro-benzol mixed in such proportions that when exploded the hydrogen of the dinitro-benzine or dinitro-benzol burns and forms water, and the carbon of the same material forms carbonic acid at the expense of the oxygen contained in the nitrate conjointly with the oxygen contained in the dinitro-benzine. He has also had in view the protection of the nitrates from the influence of moisture, and for this reason the dinitro-benzine or dinitro-benzol, which is a solid, is pulverized, as is also the solid nitrate, and both are then mixed and heated by steam in suitable molds to 212° F., which causes the dinitro-benzine or dinitro-benzol to melt between 176° and 212° F., and to completely envelope the particles of saltpeter or other nitrate used. The mass solidifies in cooling, and is molded into cartridges or bodies of any suitable shape, or it may be pulverized or granulated.

He has found the following proportions of ingredients to give the best results: dinitro-benzine, one part, and nitrate of ammonia, at least 1.9 parts; dinitro-benzine, one part, and nitrate of potassa, 0.96 part; dinitro-benzine, one part, and nitrate of baryta, 1.24 parts; dinitro-benzine, one part, and nitrate of soda, 0.81 part.

The above proportions are so selected as to yield or form carbonic oxide and water on explosion.

If the proportion of saltpeter or other nitrate be increased about three times, carbonic acid and water will be formed, which gives the best results for mining purposes.

He states the advantages of this explosive as: Impossibility of explosion from shock or blow; non-ignition by fire; possession of more power than other high explosives; non-congelation at a low temperature; pulverization without danger previous to use; safety in transportation and storage; advantageous use in coal mines in place of gunpowder, and requiring from a fourth to a fifth only of the quantity.

He claims: 1. An explosive compound composed of a nitrate salt and dinitro-benzine or dinitro-benzol substantially as and for the purpose specified; 2. an explosive compound composed of nitrate

of ammonia and dinitro-benzine or dinitro-benzol, substantially as described.

In his improvements relating to the manufacture of nitrocellulose or pyroxyline, English Patent 20,978, Dec. 23, 1890, G. M. Mowbray uses, as raw material, cotton rags, cotton lint from cotton-seed hulls, and other materials, instead of fine pure unsized cotton tissue paper, and first steeps it in a bath of a salt, preferably a nitrate, and then passes it between rollers and slowly dries it. The salt crystallizes in the cells of the fiber, and this action opens up the cells so that when the material is subsequently immersed in the acid bath, nitration takes place more rapidly and is effected at less cost than by the present process. It is pointed out that, although a nitrate is preferred, "any salt crystallized, or even water crystallized by freezing, in the cells of the fibrous cellulose, facilitates nitration by rendering the inner walls of the cellular tissue more readily accessible to the acids of the immersion bath."—*Jour. Soc. Chem. Ind.* **10**, 271; 1891.

U. S. Letters Patent No. 454,281, June 16, 1891, have been granted Hiram S. Maxim for "Method of Making Gun-Cotton." He claims to render available, by this method, all the valuable properties of the acids, and to be able to use such acids until they have become entirely spent, or until they have parted with nearly all their constituents that go to effect the nitration of the cotton. The method involves the employment of a series of six receptacles or vats filled with a mixture of the strongest acids procurable. These vats are arranged on a table or platform, mounted so as to turn about a central pivot or shaft.

In using this apparatus a given quantity of cotton is immersed, say, in vat 1. It is then removed and freed from the excess of acid by any suitable means, such as a centrifugal separator. The acid separated from the cotton is returned to the vat from which it was taken. The cotton is then immersed in vat 2, and again freed from the absorbed acids by the separator, the table, prior to such separation, being turned so that the acid from the discharge of the separator will be delivered to vat 2, from whence it came. In the same manner the cotton is dipped in succession in each vat, and the surplus acid squeezed from it back into its appropriate tank. After successive charges of cotton have thus been treated the acid becomes weakened or spent, that in the first vat of the series to the greatest degree, and

in each succeeding vat to a less extent. As long, however, as the strength of acid in the last vat is sufficient to secure the desired result and there remains in the first vat sufficient strength to partially convert the cotton, no replenishing of the acid is necessary ; but as soon as the acid in the first or last vat of the series falls below the required strength, the spent acid from vat 1 is replaced by fresh, strong acid ; thus, in the order of the strength of acid contained in them, vat 2 now becomes the first of the series or that containing the weakest acid, and vat 1 the last of the series. The subsequent charges of cotton are then immersed in vat 2 first, and in vat 1 last, until the spent acid in vat 2 is replaced by fresh, strong acid, when in its turn vat 3 becomes the first of the series, and so on. In this way all the suitable properties of the acid are utilized, the weakest acids becoming weaker by the partial conversion of the cotton which they affect, while the last immersions of each charge of cotton are in the strongest acid.

The invention is not limited to the special apparatus described, in which a conventional form of centrifugal separator is employed ; and any suitable means may be used for expressing the acid from the cotton.

He claims as his invention :

1. The method of manufacturing gun-cotton by immersing or treating charges of cotton in a given order in each of a series of receptacles or vats of acid, and as the acid in said vats becomes spent or weakened, replacing the weakest acid of the first vat of the series with fresh, strong acid, and changing the order of immersion or treatment of the succeeding charges of cotton in accordance with the relative strength of acid in the series of vats.

2. The method of manufacturing gun-cotton, which consists in immersing or treating charges of cotton in a given order in each of a series of tanks or vats of acid, and expressing from the cotton the excess of acid taken up by it and returning such excess to the vat from whence it was taken, then as the acid in said vats becomes spent or weakened, replacing the weakest acid of the first vat of the series with fresh, strong acid, and changing the order of immersion on treatment of the succeeding charges of cotton in accordance with the relative strength of the acid in the series of vats.

Hilaire De Chardounet, of France, has been granted U. S. Letters Patent No. 455,245, dated June 30, 1891. He also holds an English patent for the same invention.

The invention introduces certain improvements in the manufacture of nitrocellulose or pyroxyline, which pertain to the processes of nitration and washing, and the recovery of the acids.

It is said that the processes used permit the reduction to a minimum of the waste of acids, and the obtaining a pure pyroxyline, the nitration of whose fibers differs only in a very small percentage.

The nitration is effected by introducing cotton fiber or any other cellulose (ramie, hemp, purified wood pulp, rags, etc.), previously well dried by heat, into large pots previously filled about three-quarters full with the acid mixture, prepared in the ordinary proportions and kept at a fixed temperature by a steam-jacket. The concentration of the acids and the temperature are determined, as usual, by the degree of nitration desired; *e. g.* if it is desired to obtain a soluble pyroxyline, to one kilogram of dry cotton use twelve liters of nitric acid at the density of 1.34, and 18 liters of sulphuric acid at the density of 1.83. After leaving to soak for a time, which may vary from 1 to 24 hours, or even more, the pots are raised and poured into a centrifugal machine lined with lead or caoutchouc. By this machine the acid is extracted and run off into a reservoir, after which the communication with the reservoir is shut off and the material is washed.

The washing is done by the use of a large quantity of water, and either by removing the acid fiber to a separate vat or by leaving it in the centrifugal machine, in either case taking care to prevent any increase of temperature.

The recovery of the nitric acid left in the mass by the centrifugal machine may be made as follows: The first rinsing water may be neutralized either by adding each time an alkaline carbonate, or by placing at the bottom of the vat some fragments of limestone. A new quantity of pyroxyline may then be rinsed in the same water without inconvenience, and this may be repeated successively until this water is sufficiently charged with nitrate to be advantageously evaporated. The nitrate of lime, if desired, may be transformed into alkaline nitrate by sulphate of soda (always existing in abundance in the manufacture of nitric acid), and the nitrate of soda, after being revived, may serve anew in the manufacture of nitric acid. After the first rinsing the material is deposited in a centrifugal machine so constructed that it may be filled with water. The first centrifugal may serve the purpose if thus constructed. The material is then successively dried by the centrifugal action, and washed with a large

quantity of water while turning the machine slowly. This succession of drying and washing permits a perfect cleansing to be rapidly effected by twelve or fifteen alternations. All the washings should be made with pure water as cold as possible. For wetting the fiber between the centrifugal drying operations the machine may be turned slowly and the water thrown on the mass of pyroxyline; but the water must be very pure in order not to leave any deposit in the mass.

It is claimed the invention has the following defined novel features or improvements, viz. The described improvement in the manufacture of pyroxyline, consisting in the successive steps of nitration, centrifugal extraction of spent acids, washing of the pyroxyline, and neutralization of the wash water by an alkaline or basic material for the recovery of the residue of nitric acid left in the pyroxyline by the centrifugal action.

The described improvement in the manufacture of pyroxyline, consisting in the successive steps of nitration, centrifugal extraction of acids, washing with water to remove the acid left after the centrifugal extraction, neutralization of the acid in this water, and its re-use with successive quantities of pyroxyline, and successive alternations of washing with water, and centrifugal dryings of each quantity of pyroxyline.

In his description of the "Preparation of Cotton-Waste for the Manufacture of Smokeless Powder," *Centrbl. f. Textil. Ind.* **21**, 975; 1890, A. Hertzog states that the military authorities require a cotton which, when thrown into water, sinks in two minutes; when nitrated, does not disintegrate; when treated with ether, yields only 0.9 per cent of fat; and containing only small traces of chlorine, lime, magnesia, iron, sulphuric acid, and phosphoric acid. The waste from the spinning machines and the looms is boiled with soda-lye under pressure, washed, bleached with chlorine, washed, treated with sulphuric or hydrochloric acid, washed, centrifugaled, and then dried. When the cotton is very greasy it is first boiled with lime water. The loss in these treatments varies largely; for example: Moisture, 3-15 per cent; packing, and in transit, 2-5 per cent; boiling and washing, 5-40 per cent; bleaching, 1.5-20 per cent.—*J. Soc. Chem. Ind.* **10**, 161; 1891.

U. S. Letters Patent No. 420,445, of February 4, 1890, have been granted Joseph R. France, who claims to have invented certain new

and useful Improvements in Soluble Nitrocellulose and its Process of Manufacture.

According to his statement, soluble nitrocellulose as hitherto made is not uniform in its character and qualities. His object is to secure an article that is uniform in these respects, and therefore reliable for the purposes to which it is adapted, and this by an easier and more certain process than that hitherto employed.

Heretofore it has been customary, according to one method, to first free the cotton from impurities by washing it in an alkaline solution; second, wash it in pure water; and third, dry it. It is then passed into a bath containing the mixed acids, which are kept at an even temperature of about 60° , by means of ice in hot weather and warm water in cold weather, and there allowed to remain for a length of time, according to the condition and nature of the fiber, the strength of the acids, etc., until the desired chemical changes are supposed to have taken place. When it is removed, the acid is first pressed out by repeated plunging into clear water. Some objections to this method of treatment are, that the action of the mixed acids upon the cotton fiber is slow, irregular and imperfect, and cannot be subjected to any uniform rule. Both expense and care are required to maintain the even temperature, notwithstanding which, some lots will reach the point of "nitration" much sooner than others, necessitating constant watchfulness.

His explanation of the slow, irregular and imperfect action of the acids in the above-mentioned process is, that however uniform the mixed acids may be in strength and proportions, and however carefully the manipulations may be conducted, there are variable elements found in different samples of cotton which defy prognosis and defeat any regular system of rules. The cotton fiber has for its protection a glazed surface, as it were, enameled by nature. It is tubular and cellular in structure, and contains a natural lubricating semi-fluid substance, composed of characteristic oil, or gum, or water, or other material, or a combination thereof. Both the glaze and the lubricating substance vary with the soil, the climate and other accidents of growth, as do other characteristics of the fiber. The tubes of the fiber seem to be open at one end only, when the fiber is of normal length.

Some or all of these elements play their parts in resisting or otherwise modifying the action of the acids upon the fiber. When the cotton is subjected to the action of the acids in its natural state and

length of fiber, the line of least resistance seems to be by way of the inside of the tubes constituting the fiber of the cotton, into which they are taken in part by capillary attraction, subject to change themselves as they progress, and to the increased resistance from the oil or the gum, etc., in their progress, and therefore to modified action, the result of which is slower and slower and otherwise more and more imperfect chemical change. It may also be that the power of capillary attraction is balanced in the tubes by air contained therein, after a little, sufficiently to prevent the acids from taking full effect. These objections he overcomes in the manner to be shown hereinafter.

Another method consists in making the cotton up into yarn and hanks, and treating it in that form with acids in the usual manner. It is found that the twisting of the fibers and the disposition in the yarn form, and the forming of hanks therefrom, causes a certain resistance to the penetration and to the action of the acids, with the result that parts of the fibers are not acted upon or acted upon imperfectly.

Still another method consists in taking paper expressly prepared from cotton fiber for the purpose, passing it through the acids, washing, drying, grinding, etc., as before described. In this last case the fibers are of course modified both by the chemical and also by the mechanical treatment to which they have been subjected in the preliminary preparation of the paper; but if the oil or gum or the glaze has been attacked by them, and if they, all of them, have been removed by subsequent washing, etc. (which is very difficult, if not impossible to do), the character of the cotton fiber itself seems to have been changed chemically, mechanically, and by felting, so that the cellulose product of the paper process is not uniform or otherwise always satisfactory. In all these methods temperature is found to be an important condition.

He uses the cotton fiber in its natural state, made pure and free from extraneous substances as possible, but cut, pulverized or ground in advance as fine as possible, even to a dust, by the mechanical means and to the extent set forth in an application filed by him February 5, 1884, Serial No. 119,845, and in that condition subjects it to the acids and to all the subsequent manipulations required to produce soluble nitrocellulose, to be described hereinafter. The principle of his method is that, whereas in the first-named old process the acids attack the fiber, say of half an inch or an inch in length, from one

end and the outside, in his process, when any natural cotton dust is used, each particle will have two more mouths or openings by which the acids can enter for every additional piece into which the fiber is cut, and in addition the glaze of the fiber may be broken up by the cutting, rubbing and grinding operations to which it is subjected in advance, thereby giving the acid a better opportunity for external attack as well. In his method the cotton fiber becomes a homogeneous mass of particles or dust, consisting of very small bits of the material, each one of which is attacked by the acids and by coming in contact with the same, the result being uniform in character in the time required for nitration, and also in the uniform equivalents of nitrogen taken up in producing the desired product.

The cotton dust is placed in a bath containing the mixed acids in the usual well-known proportions required to produce the article at any ordinary temperature—between 40° and 90° F.—and allowed to remain for a uniform length of time, in proportion to the strength of the acids, until the point of nitration is reached. The surplus acids may be removed by pressure or extraction, or the nitrocellulose may be left in the acids for an indefinite length of time, according to convenience, without change, or injury, as in the process now in use.

He states that: "In my process I avoid several of the operations employed in the methods previously described, and I substitute an improved base or material to be treated, having superior qualities for the purpose, which enable me to omit some of the steps required where other base material is used, as follows:

"1. I do not find that it is necessary to wash either the cotton fiber or the cotton dust in any alkaline solution. Consequently, I omit that operation entirely, and find that I produce a superior article of nitrocellulose when it is omitted, and this with certainty in each and every instance.

"2. The washing in pure water and the drying are therefore omitted also.

"3. The watching and constant attention to the temperature I also avoid.

"4. I avoid the loss of material which occurs from premature or imperfect nitrations, and the danger of spontaneous combustion.

"5. I avoid the want of uniformity in the resulting product.

"6. I avoid both capillary obstruction and much of that arising from the enamel or glaze of the fiber.

"Among the advantages resulting from the use of my cotton dust are the following:

“ 1. The product is always uniform both in appearance and chemically, and will remain stable for a long period.

“ 2. It is always evenly soluble.

“ 3. It is not liable to spontaneous combustion.

“ 4. The remaining acids are more easily and more thoroughly washed out after the point of nitration has been reached.

“ 5. My soluble nitrocellulose can be more cheaply produced, since waste is avoided and time is saved in washing.

“ 6. Less watching of the process of nitrogenizing is required.

“ The fact that the cotton is in the form of dust, and in that finely comminuted form is acted on more quickly and perfectly by the acids, is important also, and has its proper effect in the washing stage above mentioned, giving more prompt and complete access to the water and egress to the acids.

“ The soluble nitrocellulose made from my cotton dust is distinguishable from its cotton dust base by its explosive quality, and by a certain dull uniform massed and slightly felted appearance, showing that it has not been subjected to mechanical disturbance subsequent to its subjection to the action of the acids. In other respects it corresponds in appearance to the cotton dust from which it is made. It is distinguishable from the highly explosive or insoluble nitrocellulose by the fact that it can be dissolved in the usual preparation of ethyl, or grain alcohol and ether, as used in making collodion, or in methyl or wood alcohol of 95 per cent to 100 per cent. It is distinguishable from soluble nitrocellulose made by the old process, which has been reduced to dust subsequent to subjection to the acids, by its appearance, as above stated, showing that it has not been subjected to mechanical disturbance subsequent to its subjection by the action of the acids.

“ In practicing this invention I find that taking one-pound batches of finely ground cotton, which is immersed in the mixed acids of varied proportions according to solubility required for a good soluble nitrocellulose, a proportion of eight (8) parts nitric acid 42° Beaumé and of sulphuric acid twelve (12) parts 66° Beaumé, is suitable. The cotton is stirred into the bath of mixed acids for fifteen (15) minutes, the superabundant acids are pressed out, and the cotton then washed in successive waters until entirely free from acids. Using cotton dust, I can thus nitrate effectively at an ordinary temperature—say from 50° to 100° F. I usually prefer to keep the room in which the nitration is carried on at a temperature of about 75° F., but I find no

perceptible difference in the nitrations at ordinary temperatures, as before stated, and I attribute the advantages over the old methods here indicated to the use of the cotton dust, as stated herein; but I do not desire to limit my invention either to the exact proportions of the acids or to the exact temperature above set forth, as by the use of my cotton dust I am able to vary the range both of proportions and of temperature greatly and yet accomplish the purpose of my invention in a superior manner.

“I am aware that it is not new to produce an impalpable powder from cellulose by the use of chemicals and afterwards treat the same for the production of pyroxyline or nitrocellulose, and this I do not claim.”

What he does claim, as his invention, is as follows :

1. The process of making nitrocellulose, which consists in mechanically reducing cotton to a uniform and homogeneous dust-like condition, and then subjecting it to the action of a bath of nitric and sulphuric acids in about the proportions and at the temperature stated.

2. The process of making nitrocellulose, which consists of subjecting mechanically comminuted cotton in a homogeneous dust-like condition to the action of a bath of nitric and sulphuric acids in about the proportions and the temperature stated.

3. As an improved article of manufacture, soluble nitrocellulose composed of pure mechanically comminuted cotton fiber nitrated, substantially as described.

U. S. Letters Patent No. 457,002, August 4, 1891, have been granted Ebenezer Kennard Mitting, for a “Process of Making Nitro-Glycerine.” In his specification, after referring to the usual manner of making nitroglycerine in the three varieties known to chemists as mononitro, dinitro, and trinitro-glycerine, and of which the trinitro is the only variety which is of practical utility as an explosive, he states that the operation is defective, owing to the fact that the last portions of the glycerine added to the acid are not converted into trinitro-glycerine, by reason of the weakening of the acid mixture by the water formed in the reaction earlier in the operation, the presence of a comparatively large excess of anhydrous or nearly anhydrous nitric acid being essential to thoroughly convert the glycerine into trinitro-glycerine. Consequently the full theoretical yield of nitro-glycerine (or a close approach thereto) is never obtained in practice,

a certain loss always resulting from such portion of the glycerine which has not been converted at all, or only converted into the mononitro variety, being dissolved in and carried away by the wash water, while another and variable proportion may have been converted into the dinitro variety, and a portion of this may remain after washing together with the bulk of the trinitro, reducing its specific gravity and explosive force. Various means have been proposed to overcome this defect and improve the yield of trinitro-glycerine. It was thought that the admixture of the acid with the glycerine in thin streams, allowing the whole to presently run into a collecting tank, would overcome the difficulty; but this device did not succeed, owing to the fact that the reaction is not completed, except (as stated above) in the presence of a large excess of anhydrous nitric acid. Consequently the same conditions were brought about in the collecting tank as obtained in the case of running the whole of the acid first into the tank and then adding the glycerine slowly, viz. that the last portions of the glycerine were not fully converted. Again, it was proposed to first treat the glycerine with only a portion of the usual amount of acid to remove the spent acid and then treat with the remainder, and for the better prosecution of this process to vary the quality of the acids used for the first and last treatment, and even to make the process a continuous one. So far as he was aware, this mode has not proved successful in practice, because it fell short of providing the necessary excess of nitric acid at the close of the operation. It has also been proposed to use double and treble the usual quantity of acid; but this device has not been successful, and on the other hand the cost has been so largely increased as to be almost prohibitive.

The object of his invention is to overcome the difficulty above set forth and to convert the whole or practically the whole of the glycerine into trinitro-glycerine, and thus produce a yield more nearly approaching the theoretical quantity, and to effect this improvement without the use of additional acid beyond the usual quantity now employed.

In carrying his invention into effect, he first proceeds with the nitration of the glycerine in the usual manner, viz. by charging the nitrating vessel with the mixed acid, say about 8 parts, by weight, for every 1 part of glycerine to be nitrated, and at the close of the operation and after separation has taken place he draws off the spent acid in the usual manner. In the meantime he prepares another lot

of mixed acid for the next succeeding lot of glycerine; but before using it for such next lot he runs into and mixes with it the nitroglycerine produced from the first operation. The effect of this is to expose the nitroglycerine produced in the first operation to the full effect of the large charge of anhydrous nitric acid intended for the second operation, and thus convert any of the lower nitroglycerine into the trinitro variety. After allowing the mixture to settle he draws off the supernatant trinitro-glycerine to the washing tanks and proceeds with the nitration of the second lot of glycerine with the acid (originally intended for it) in the usual way, and the nitroglycerine thus produced is in its turn fed into and mixed with the lot of acid for the next succeeding nitration, and so on continuously, using always the fresh acid first upon the last preceding lot of glycerine which has been nitrated, and then to nitrate a fresh lot of glycerine, as described. The fresh acid after acting upon the product of a previous nitration contains a little water, such water being that produced in the reaction, as will be readily understood. This, however, is of comparatively small amount and does not seriously affect the succeeding nitration, especially as same is in reality completed by exposure to the next lot of fresh acid.

The foregoing operations he performs in one nitrating vessel by proceeding as follows: he first nitrates a charge of glycerine in said nitrating vessel and allows the mixture of nitroglycerine and spent acid to settle and separate, and then draws off the spent acid only, leaving the nitroglycerine in the nitrating vessel. He next runs into that nitroglycerine the charge of mixed acid intended for the next nitration (this operation is performed quickly and with perfect safety under the usual precautions), and having mixed the liquids he allows them to settle and separate, and next draws off the supernatant nitroglycerine (to be washed and otherwise dealt with) by a faucet fixed at a proper level, or equivalent means, leaving the acid in the nitrating vessel ready to receive a charge of glycerine, which he now runs into it. He next allows the mixture to settle and separate, draws off the spent acid, and proceeds to run into the nitroglycerine the charge of fresh acid, as before, and so on in regular order, as described; or two or more nitrating vessels may be employed and preferably fixed at different levels, as will be readily understood by those versed in the art. By working in this manner an increased yield of nitroglycerine is obtained, of full specific gravity and explosive power, without increased quantity of acid beyond that usually

employed, and at only a slightly increased cost for manipulation, which is more than repaid by the increased yield, quality, and safety, as the fully converted trinitro-glycerine is far less liable to spontaneous decomposition than a mixture of such nitroglycerine with lower nitro compounds.

He claims :

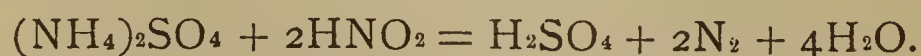
1. The improvement in the method of manufacturing nitroglycerine, which consists in first nitrating a charge of glycerine and separating the product from the spent acid, then treating said product anew with a fresh charge of nitrating acid in excess, and finally separating the nitrated glycerine from the fresh excess charge of acid, substantially as described.

2. The improvement in the method of manufacturing nitroglycerine, which consists in first nitrating a charge of glycerine and separating the product from the spent acid, then treating said product anew with a fresh charge of nitrating acid, separating the nitrated glycerine from the acid, and employing the acid to nitrate a second charge of glycerine, substantially as described.

3. The improvement in the method of manufacturing nitroglycerine, which consists in first nitrating a charge of glycerine and drawing off the spent acid, next treating the product with a fresh charge of nitrating acid, then drawing off the nitroglycerine and nitrating a fresh charge of glycerine with the same acid, and repeating the operation in the same nitrating vessel, substantially as described.

The *Scientific American Supplement* 27, 11070-11071; April 13, 1889, copies from *La Nature* an article by M. Vuillaume, late director of the dynamite factory at Cengio, Italy, on the "Manufactures of Nitroglycerine," which is illustrated by a number of drawings showing the apparatus used and the method of working it.

Eduard Liebert, of Berlin, has been granted two patents for methods of treating nitroglycerine. In the first he seeks to render nitroglycerine uncongealable by adding to it isoamyl nitrate. This addition, while it may not prevent freezing in all cases, is likely to weaken the effect considerably. In the second, he adds ammonium sulphate or nitrate to the acid mixture during nitration, to destroy the nitrous acid formed according to the following equation :



—*Ding. Poly. Journ.* 278, 19; 1890.

U. S. Letters Pat. No. 449,687, April 7, 1891, have been granted Hiram S. Maxim for "Process of and Apparatus for Making Explosives."—III.

His invention relates to the manufacture of explosives of the kind or class known as "nitro compounds" or "nitrated explosives," such as nitroglycerine, gun-cotton, and the like, which result from the combination or composition with glycerine, cellulose, or the like, of nitric acid or other suitable nitrating compounds.

In his specification he describes the invention as applied to the manufacture of nitroglycerine only; but its applicability to the treatment or manufacture of other explosive compounds of a similar nature is to be understood.

The main objects of the invention are, first, to produce any desired quantity of an explosive by a continuous process or operation, and, second, to bring the acid or nitrating agent and the glycerine, or other material to be acted upon thereby, into intimate contact with each other while both are in a very finely divided condition. These objects he accomplishes by bringing the glycerine or other material in the condition of spray into a stream or current of acid spray.

In carrying out the invention practically, the mixing of the nitric acid or nitrating agent and the glycerine is effected by means of an injector operated by cold compressed air or by a cold air blast. The suction produced by the current of air flowing through a nozzle forming a part of the injector, draws the glycerine from a tank in which it is contained, and the current of air impinges upon and atomizes the glycerine, or scatters it in a fine spray. The acid is similarly drawn from another tank and blown into a fine spray, and the two substances while in this finely divided condition are caused to intermingle in the presence of air which is rapidly expanding and of which the temperature is rapidly falling. The atomized acid and glycerine are together blown into, and conveyed through, a mixing pipe or tube, and after issuing therefrom they are washed or quenched by a copious spray or jet of water, and collected in a suitable receiver.

The apparatus, as described, consists of a nozzle entering a "chamber" provided with a nozzle, entering the enlarged end of a "tube," the three concentric parts forming a double injector, of which the inner or first nozzle is connected with a receiver of air compressed by a suitable pump to a pressure of about 100 pounds to the square inch. Which pipe enters the "chamber" back of the orifice of the inner or first nozzle, contains a suitable cock, and leads from

a tank or receiver. A second pipe, provided with a cock, leads from a second tank or receiver and enters the "tube" back of the orifice of the nozzle of the "chamber." One of the tanks is to contain the acid or nitrating agent and the other the material to be combined therewith, and both are provided with glass gauge tubes to indicate the levels of the liquids therein.

The first mentioned "tank" is filled with glycerine, and the other, to the same level, with acid. The air is then allowed to flow through the first or inner nozzle. The current of air issuing from this nozzle produces a partial vacuum in the "chamber," which, upon opening the cock of the pipe connecting with the tank of glycerine, draws the glycerine in. The air impinging upon the glycerine atomizes it and forces it in a spray through the nozzle of the "chamber." The air-jet and spray issuing from this nozzle produce in like manner a partial vacuum in the "tube" back of the orifice of said nozzle, and this draws in the acid, which, meeting the jet, is blown into spray and mixed with the atomized glycerine. The air being kept under a high pressure in the reservoir, a considerable amount of refrigeration will take place in the nozzle of the "chamber" and in the "tube" by reason of its expansion in these places, and the temperature of the acid and the glycerine will thus be prevented from rising too high.

The "tube," into which the atomized mixture of acid and glycerine is blown, serves as a mixing chamber, and should be of considerable length, so that the materials may have ample time while in the same to complete their reactions on one another in the manner required. It may be from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter at the part which surrounds the injector nozzle, and for a distance of, say, 16 inches, or thereabout, from the said injector, and may gradually increase in diameter beyond this point until it reaches a collecting tank. It is, moreover, advantageous to arrange said "tube" with a fall toward the collecting tank of about 1 in 15.

The length of the "tube" or mixing pipe may be from 100 to 200 feet, more or less, and a wall or mound of earth may be built between the injector and the collecting tank to serve as a protection to the operator. The "tube," as well as other parts of the apparatus, may be surrounded by a water-jacket, through which a circulation of cool water is maintained for keeping down the temperature of the explosive compound.

Prior to entering the collecting tank the current of spray is met by a stream or a number of jets of cold water from a nozzle inserted in

the top of the collecting tank above the "tube" or mixing pipe, which serves to cool or quench it as it enters the collecting tank.

The tanks for containing the acid and the glycerine are preferably arranged side by side above the injector and mixing pipe or "tube," and should be made of such relative capacities or dimensions that they will contain the required proportions of acid and glycerine, and will therefore both be emptied at the same time.

The quantity of explosive material operated upon at any time is very small. The collecting tank should, however, be of large dimensions, so that it will contain a great quantity of water.

The acids and glycerine being blown into a fine spray, as above described, an instantaneous nitration will be effected, while the expansion of the air, as it issues from the injector, serves to lower the temperature. Moreover, it is claimed for this apparatus that the chemical reaction may be readily controlled, and that, should any undue production of heat take place or nitrous fumes be developed, the supply of air to the injector may be increased and the temperature thus brought down.

In cases where the space available for the apparatus does not admit of the use of a long mixing pipe or "tube," such as is described, the "tube" is carried direct to a tank surrounded by a water-jacket. A pipe leads from this tank, from or near its bottom, back to the mixing chamber or space at the rear of the nozzle of the "chamber." This pipe contains a cock, which, while the atomized acid and glycerine are being mixed, is closed. When a quantity of explosive has been thus made, the acid and glycerine supply pipes are closed and this cock opened. The continued flow of air under pressure produces a rapid flow of the mixture from above pipe back into the collecting tank. The expanding air with its refrigerating effect keeps down the temperature, while by the circulation and agitation the substances are thoroughly and intimately mixed.

An air vent is provided in this collecting tank, and the same disposition as in the previous case may be used for quenching the mixture by jets of water.

The subsequent treatment of the nitroglycerine or other compounds made by this process may be the same as in the case of similar compounds as hitherto manufactured.

What he claims is :

The method or process of manufacturing explosives as described, which consists in separately atomizing or finely dividing the nitrating

agent and the material to be acted on thereby, and uniting the two or causing them to intermingle while in such condition.

The continuous process described of manufacturing explosive compounds, which consists in uniting and causing to intermingle jets of the acid and material to be acted on thereby, in the condition of spray, carrying off the spray in a mixing chamber, and collecting the resulting compound in a tank or receiver.

The method or process described, which consists in atomizing or spraying glycerine by a jet of air under pressure, separately atomizing or spraying in a similar manner a nitrating agent, and mixing the two substances while in the condition of spray.

The method or process of manufacturing explosives, which consists in separately atomizing and uniting the spray of the nitrating agent and the substance to be acted on thereby, and then quenching the mixture with water.

The combination of a nozzle, a receiver or source of compressed air connected therewith, a tube or chamber surrounding the nozzle, a tank or receiver for glycerine connected with said chamber, a second chamber, and a tank or receiver for acids connected with the same, the first chamber being formed with a contracted nozzle that enters the second or mixing chamber, the above parts being arranged in substantially the manner as set forth to constitute an injector for atomizing and mixing glycerine and acid.

The combination, with a collecting tank, a mixing tube or chamber leading thereto, and a nozzle or means of quenching with water an explosive mixture delivered from the mixing tube into the collecting tank, of an injector at the end of the mixing tube, tanks for containing acid and glycerine, respectively, connecting with the injector, and a receiver or source of compressed air for operating the injector.

The combination with a receiving tank and mixing tube or chamber, of two concentric injector nozzles, receivers for containing glycerine and acid, respectively, connected to the chambers surrounding the nozzles in the rear of the orifices of the same, and a source of compressed air, as set forth.

In discussing "Precautionary Regulations during the Preparation of Nitroglycerol," F. Scheiding, *Zeits. f. angew. Chem.*, 1890, 609-613, first suggests that the mixing of the acids should be made in a vessel provided with a cover and chimney for conveying the acid fumes out of the building. The mixing can be effected by means of

compressed air, and the cover prevents any of the acids from being thrown out of the vessel. Montéjus should be made of cast or wrought iron, preferably not lined with lead. Cast iron withstands the action of the acid better than wrought iron, but is liable sometimes to crack, especially when the air-cock is opened. This cock should therefore be placed outside of the building or separated from the montéjus by a wall, and the montéjus should stand clear of everything, so that any leak can easily be observed. In the next operation, which properly may be called dangerous, viz. the nitration of the glycerine, rise of temperature which might lead to explosion may be caused by impure glycerine or the accidental admixture of water. The chemical examination of the glycerine is therefore essential.

The nitrating vessel must be made of thick lead and stand clear on all sides in a well lighted building, yet not exposed to the direct rays of the sun. The contents of the nitrating vessel should be kept cool by several separate coils of thick leaden pipe, through which cold water passes. In order to prevent any water from escaping into the acid mixture, should one of the worms be damaged during the operation, the cooling water should flow from a higher lying vessel and discharge into a lower lying tank. The cooling worm would thus act as a syphon and draw some of the acid and nitrogen mixture into the lower tank, where its presence would be recognized by the turbidity produced, or by means of litmus paper. The agitating or stirring is best effected by compressed air, and the workman should always ascertain by means of a manometer whether there is sufficient air pressure before commencing the nitration. In order that no water may be carried over with the air, a condensation box should be fitted at the lowest point of the air pipe. The nitrating vessel must be provided with a cover or hood and chimney, which will convey the acid fumes out through the roof. The whole apparatus should stand over a large tank containing water, into which the whole contents of the nitrating vessel can be promptly discharged through a large earthenware cock, should the temperature rise to 40° C.

The floor of this building in certain districts consists of sand, in others of clay. The author prefers a clay floor slightly sloping towards a gutter in the middle which passes underneath the door. The floor should be kept always damp and covered with sawdust, and the place where the men stand covered with a soft mat. The mat should be washed twice a week, and the sawdust renewed once a week and the removed sweepings burned.

The author suggests the erection of one or two shelter huts, in which one or two workers could take refuge when an explosion threatens, and be protected from falling pieces. An alarm horn should be hung in the shelter hut, by which a warning signal could be given for the whole factory. As explosions have been caused in other buildings by debris falling through the roof, the author advises that the roofs of the buildings in which nitroglycerine or dynamite is present should be provided with a strong double lining. The intervening space would also keep the building cooler in summer and warmer in winter. An electric bell should be near the nitrating apparatus, by which a signal could be sent to the laboratory in the event of anything unusual occurring during the operation. The plug of the discharge cock should be carefully examined before each operation to see that it is quite free from any grit or frozen nitroglycerine.

For conducting the nitroglycerine and waste acids through the mound surrounding the building, a brick channel thickly covered with tar is recommended, just sufficiently wide to take an open leaden gutter, through which a leaden pipe can be pushed. This pipe can be daily cleansed by rinsing first with concentrated sulphuric acid and then with water.

The author considers the combination of the nitrating apparatus with the separator in one building as injudicious. The separator should be provided with a perforated pipe for compressed air, that in the event of heating taking place, which often occurs only at separate spots, the mixture could be agitated and the danger possibly avoided. It should also have electric thermometers which would ring a bell when a certain temperature was reached. The separator should also have a hood with chimney passing through the roof. Outside of the mound surrounding the separator house there should be a pipe for compressed air, with a cock by means of which the agitation of the liquid in the separator could be started, should the workmen have fled from the building on signs of danger without starting the air agitator. Should the bells in connection with the thermometers cease ringing, the building can safely be re-entered. An essential condition of safety is that all the apparatus should be carefully examined daily, to see if it is in proper working order. After the nitroglycerine has passed to the washing house the most dangerous operations are passed. There the greatest cleanliness should be observed and care taken that no wash water, which always

contains some nitroglycerine, is splashed about. The nitroglycerine must be washed quite free from acid.

Dr. Thomas Darlington, in treating of "The Effect of the Products of High Explosives, Dynamite and Nitroglycerine, on the Human System," says in the *Medical Record* 38, 661-662; 1890: When dynamite or nitroglycerine is used in open-cut work, as on our railroads, after the explosion the gases immediately distribute themselves in the atmospheric air, and no effect has been noticed on the workmen employed. But when used in tunnels, as in mining or other partially closed cavities, where the gases or residues are slow to escape from the mouths of the tunnel, or up air shafts, serious deleterious effects are produced.

There are, for purposes of study, practically two classes of dynamite, which might be termed inorganic and organic, according to the absorbent used. A type of one class is that made with infusorial earth, and of the other, that made with wood pulp or sawdust. Others still are made from a combination of both. The results of the explosion, however, are practically the same in either case, except that with the organic absorbent we get with the products an additional amount of carbon.

An experience of over five years where such explosives have been in use has led me to believe that an article on this subject might be of interest to some of the medical profession.

During 1885 to 1887, while surgeon to the New Croton Aqueduct, fully thirteen hundred cases of asphyxia, or partial asphyxia, and poisoning, from the products produced by the explosion of dynamite, came under my care; and more recently a few other cases which I have had better opportunity to study.

Two classes of cases were observed: First, where a considerable quantity of the products was inhaled at one time—acute cases; second, where the men constantly breathed a small amount, or chronic cases. The acute cases varied according to the amount inhaled.

In some cases where the amount of dynamite used was not large, or where, after the explosion, a considerable quantity of fresh air has been mixed with products of combustion, or where the workman has after a few breaths become giddy and is pulled away by others and sent to the surface, the effects produced are a trembling sensation, flushing of the face, succeeded sometimes by pallor, frequently

nausea, sometimes vomiting, with throbbing through the temples and fullness in the head as if it would burst, followed by an intense headache characteristic of poisoning by nitrites—similar to that of nitrite of amyl, only not so violent, but more persistent, frequently lasting forty-eight hours. The heart's action is increased, and the pulse full and round, though somewhat compressible.

Case I.—J. C——, occupation miner, while returning to work after a blast, became dizzy, and crawled on hands and knees back to the bucket; felt as if drunk. About twenty minutes afterward was nauseated and vomited slightly. Had a feeling as if his head was swelled. After vomiting the headache increased. The pulse at this time was full and bounding and 108. Ten hours afterward the headache was more pronounced, and the pulse 88 and more compressible.

Where, however, a man goes into the tunnel immediately after the explosion, and is brought in contact with a large percentage of the poisonous materials, the effects are giddiness immediately followed by unconsciousness, and the patient presents the usual appearance of asphyxia. Sometimes in these cases the pulse is full and bounding, though very compressible; but in most of the cases it is alarmingly weak. Generally there is great pallor, though this may be partially due to working underground. The comatose condition soon passes away, and is succeeded by drowsiness, languor, cold perspiration, intermittent pulse, and generally nausea and vomiting. Sometimes the breathing is spasmodic, and frequently there is hic-cough, and after a time a severe headache.

Nearly all of these cases, however, no matter how serious they seem at the time, recover; though a substitute on the Aqueduct, during my absence, was on one occasion so unfortunate as to lose two cases. I found upon inquiry that death in these cases occurred several hours after the patients were removed from the tunnel, and was due to paralysis of respiration.

In the chronic cases there are four prominent symptoms: Headache, cough, indigestion, and disturbances of the nervous system.

The cough is similar in character to the cough of pertussis or of malaria, and at first I was under the impression that it was purely malarial, as cases of intermittent fever were frequent. But although some of the cases may have been complicated with malaria, there were many others that were not, in which the cough was persistent.

In nearly all of the cases there was a continuing headache.

Next in prominence to these symptoms come disturbances of the nervous system, as trembling, irritability, neuralgia, etc. In fact, nearly if not all of the symptoms were attributable to this cause. Even the cough, in all probability, was due to the effect produced on the pneumogastric nerve.

One of the superintendents became so nervous and irritable, largely from this cause, that it was with difficulty that he could get along with the men. All of the men affected seemed extremely nervous. And with this was associated indigestion, probably due to the same cause. Of course, with this latter symptom, the character of the food and the manner in which it was eaten must be taken into consideration. But as soon as a man with these chronic symptoms was taken from the tunnel and placed at work on top, he steadily improved, and would finally recover entirely.

It was also noticeable that those who had previously suffered from dyspepsia or neuralgia were made much worse by the dynamite smoke.

One inspector on the Aqueduct was forced to resign by reason of the constant return of an old "tic douloureux," due to this cause. What were the symptoms recognized due to?

The formula for nitroglycerine is $C_3H_5(NO_3)_3$. And the products from the combustion of this are written:



In other words, the products are water, carbonic acid gas, and nitrogen dioxide; none of which would produce the symptoms above described except asphyxia, but not the effect on the heart, nor the other symptoms witnessed. What then was the cause?

A comparison of the above symptoms in the acute cases with the phenomena produced by various sized doses of nitroglycerine shows them to be identical. This similarity of symptoms from inhalation of the products of the explosion of dynamite, and of those produced by the nitroglycerine itself, is so well marked that even miners themselves have noticed it. Frequently, when dynamite is frozen, a miner will place a cartridge in his boot to thaw it out; and the absorption of nitroglycerine through the skin will produce precisely the same symptoms as in the mild acute cases of the inhalation of the products before described.

Again, I know an instance of where a miner used his knife to cut a cartridge, and afterward cut and ate an apple with the same knife.

In this case, according to his statement, the symptoms were similar to being "knocked out by powder smoke," only more severe. The headache persisted three weeks. And on another occasion this same miner cut up some tobacco to smoke, with a knife that he had used for dynamite, and was again similarly affected. Here the heat from the tobacco inhaled smoke volatilized the fine particles of nitroglycerine on the tobacco below, and poisoning was produced by absorption through the lung tissue.

No other conclusion can well be reached than the fact that there is mixed with the gases produced, unexploded particles of nitroglycerine in a volatile state, and these particles inhaled by the miners produced the effect described.

There is no doubt but that the explosion of a large quantity of dynamite would produce sufficient gases of CO_2 and N_2O_2 to produce asphyxia. Here we get the cyanosis and other symptoms of simple asphyxia, and we may get nausea and vomiting; but not the same disturbance of the sympathetic system, nor the continued chronic spasms of the vagus, nor the persistent headache pathognomic of nitroglycerine poisoning. This fact can be conclusively proved by waving in the fumes, immediately after an explosion, a cold sheet of glass, and thus collecting upon it by condensation a small percentage of the nitroglycerine itself.

As regards treatment, as a preventative, the use of such apparatus or machinery, whether by blowing or by sucking, as will rapidly clear the tunnel or cavity from noxious gases or fumes is to be recommended. Where steam drills that are worked with an air compressor are used, they contribute largely to this end.

Also it has been found by makers of dynamite that the use of a large cap will explode a greater percentage of the glonoine than a small one, and this, to a certain extent, obviates the trouble. In certain cases, however, for some reason, a cartridge does not explode, but burns like a candle, with considerable sputtering. In such an instance the amount of nitroglycerine volatilized is much greater than if exploded, and consequently the effects far more deleterious. I have witnessed a whole "shift" "knocked out" from this cause.

Of course, such measures as are generally used in cases of asphyxia are of service. But in addition to these, the use of cold to the head, and of atropine, ergotine, or other vasomotor stimulants, administered subcutaneously, are of necessity indicated and exceedingly efficacious. There is little doubt that the effects of nitroglycerine

are produced from its decomposition and the formation of a nitrite in the body. "Treatment with ammonia restores normal color and normal functional power to nitrite-poisoned blood."

Acting on this principle, and from its stimulant properties, I have uniformly treated my cases with inhalation of ammonia, and also given the carbonate and aromatic spirits of ammonia internally; and up to the present time have not lost a case.

It seems to me it would be well for those in charge of such works to recommend to the workmen to carry with them small vials of this remedy for use in similar cases.

In none of the cases did I notice any changes in the blood—that is, darkening—such as are mentioned in nitroglycerine poisoning, but this may have been due to lack of proper observations on my part. In numerous cases of pneumonia the sputum was darker than usual, but this I attributed to the dust and lamp-smoke inhaled.*

According to W. Schuckher's English Patent 45,625, Sept. 16, 1890, for "A Process and Apparatus for the Manufacture of Nitrated Starch," starch, preferably potato starch, is dried at 100° C. and finely ground. It is then dissolved at 20° – 25° C. in nitric acid of 1.501 sp. gr., using 10 kilos. of acid to 1 kilo. of starch. The solution is added to a mixture of nitric and sulphuric acids, which, for sake of cheapness, may be the waste acid from nitroglycerine manufacture, containing about 70 per cent of sulphuric and about 10 per cent of nitric acids. Five kilos. of this waste acid are employed to every kilo. of the nitrated starch solution, the mixture being kept at a temperature of 20° – 25° C. Nitrated starch is precipitated as a fine powder and is collected on a filter of gun-cotton. The bulk of the acid is then removed from the precipitate by hydraulic pressure. The cakes produced are well washed in water and treated with 5-per cent soda solution. After 24 hours the cakes are ground between rollers, the creamy mass formed being afterwards dried by means of a centrifugal machine or a filter press. Finally about 1 per cent of aniline is added to the residue, which still contains 33 per cent of water. Nitrated starch as prepared dissolves readily in nitroglycerine. In

* Bibliography: Hunt, T. Sterry: *Am. Jour. of Sci. and Arts*, "Glonoine," Nov., 1849; Murrell, William: *Lancet*, 1879, pp. 80, 113, 225; Hay, Matthew: *Practitioner*, June, 1883; Brunton, T. Lauder: *Pharmacy, Therapeutics, and Mat. Med.*, 1888, "Nitroglycerine," p. 788; Curtis, Edward: *Reference Handbook of the Med. Sciences*, p. 189, "Nitrites."

the cold it forms at first a mass resembling lime, but as more of the nitrated starch is added a hard waxy material is produced.

A very serious accident occurred on the 13th May in a factory at Avigliana, during the manufacture of ballistite, by which 13 lives were lost. Through the Foreign Office we have obtained some interesting particulars of the accident, collected by Col. Slade, British Military Attaché at Rome. It appears that "The factory, or rather the special portion of the scene of the occurrence, is a long roofed structure, divided into five separate compartments, where the operations of milling, cutting, sifting and cleaning are carried out.

"In the first ward the ballistite, by means of a special engine, is prepared in the form of sheets, after being laid in a wooden trough fitted with double zinc plates, and subjected to the heating process by means of hot-water pipes, after which they pass to the cutting machine.

"The second ward was empty at the time of the fire, a large platform being in course of construction for the setting up of two cutting and two grinding machines.

"In the third were several cutting and granulating machines, together with a ton of smokeless powder ready prepared to be despatched to the navy.

"The fourth contained the sifting machine, and it is also supposed that upwards of two or three tons of black powder were also in the ward.

"The cleansing machine and upwards of four tons of black powder, partly packed and partly loose, were in the fifth compartment.

"All the several compartments are connected by vaulted passages, and all have an outlet by means of light glass doors; all these doors were open* when the fire broke out.

"A workman, who was standing about 70 yards off, stated that the fire broke out in the first compartment, and spread with the greatest rapidity through the other four. No dead body was found in the first ward, two were found in the fourth, and eleven crowded together at the door of the last; among these eleven were the remains of a man who at the time was working in the first compartment.

"This leads one to fairly assume that the fire originated in the

* Subsequent information throws doubt on this statement, and it seems more probable that the doors were closed, and they certainly opened inwards instead of outwards.

first compartment, either through the action of the cutting machine, or by the sudden ignition of one of the strips of ballistite through overheating.

“The bodies of the five men working in this ward were set on fire, and the poor fellows, in place of running out through the open door, fatally searched for an escape through the several compartments, thus spreading fire in every direction, to the last room, where the heat must have reached such an intensity as to have produced immediate death. All the tools and wooden implements were slightly charred, whilst the metal of those zinc-plated had completely melted away.

“The various machines did not suffer much from the results of the accident, and will be set at work again as soon as the buildings have been repaired.

“One of the walls of one of the wards was blown down and three were unroofed, the tiles falling outward. The first two wards were left almost intact. The total amount of powder destroyed may be reckoned at about 8 tons, whilst the damage is estimated at about 4000 l.”

Although nothing definite is disclosed as to the cause of the accident, there can be no doubt that the manufacture was being carried on in a very dangerous manner, with a wholly unnecessary accumulation of persons and explosive material within a single building, and with a very inexcusable neglect of what in this country would be regarded as essential precautions.

It is most important (especially when dealing with a comparatively new material like ballistite) to isolate the various processes, to subdivide the amounts of material so as to limit the effects of a possible accident, and to allow only a very few work-people within a single building or risk.

None of these things were done here, and the subdivision of the buildings into wards (as the event showed) was entirely illusory.

It has been suggested (by the Italian Director-General of Artillery) that a piece of ballistite in being carried from one machine to another may have fallen off one of the trays, and that some small grit or gravel may have adhered to it, and so brought about the explosion, when the machinery was again set in motion. This suggestion is not intrinsically improbable, but if it be accepted it would point to an even greater disregard of precautions, because one of the first efforts of the maker of explosives should be directed to the rigid exclusion of grit from danger buildings.

The one satisfactory point in connection with this accident (which in its consequences, if not in its inception, would appear to have been entirely preventible), is, that although no less than about 8 tons of ballistite is estimated to have been consumed, there was no violent *explosion*. This observation usefully supplements the results obtained in the experiments with burning the kindred explosive "cordite," which are described in the Experiment Section of this Report.*—*15th Ann. Rept. H. M. Insp. Exp.* pp. 49-50; 1891.

According to O. Guttman, *Ding. Poly. Journ.* **278**, 25; 1890, smokeless powders have been the cause of fatal accidents at Spandau as well as at Avigliana, which are believed to have resulted from the fact that the behavior of these bodies, under all conditions of production and with novel machines, is yet but imperfectly known.

Among the accidents by fire or explosion which have come under the notice of the Home Office from January 1 to December 31, 1890, we note the following due to ballistite :

The first occurred Feb. 27, at Factory No. 3, Ardeer, Ayr (Nobel's Explosive Co., Limited) :—A small "crack" occurred in the ballistite when between the rollers. The foreman felt as if something had struck his wrist, and a mark was found like the prick of a pin. Whether this was a particle of dry nitro-cotton or minute fragment of iron is unknown. The mark in the sheet of ballistite was as if made by a pin point. No one was killed or injured.

The second occurred at the same factory on March 20 :—A sheet of ballistite "cracked" in rolling and was broken, but no damage was done. No one was killed or injured.

The third occurred at the same factory on May 13 :—A small quantity of ballistite which was being rolled between steam heated rollers, took fire. No one was injured, and no damage was done.

The fourth occurred at the same factory on May 28 :—About an ounce of ballistite exploded in an experimental screw-press, about a pound of finished ballistite being ignited by the explosion. No one was injured, and very trifling damage was done to the machine.

The fifth occurred at the same factory on June 21 :—Breech-block

* It is not quite clear what is meant by "black powder," of which 4 tons were said to have been present in the fifth compartment. We conclude that it must have been black ballistite (*i. e.* ballistite treated with graphite), and not ordinary black gunpowder, which must certainly have exploded.

of sporting gun slightly cracked in experimenting with smokeless sporting powder. No one was injured. The accident was due to the detonation of the ballistite charge on firing with an ordinary percussion primer.—15 *Ann. Rept. H. M. Insp. Exp.* pp. 115-143; 1891.

In his "Novelties in the Explosives Industry and Blasting," *Ding. Poly. Journ.* 275, 111; 1890, Oscar Guttmann says since our last installment the problem of smoke-weak powders has undergone a more rapid development than has ever before been known in the history of explosive agents. The daily papers teem with surprising statements wherein powders of unlike characters are classed in one category, so that it is difficult even for an expert to determine precisely what is meant. Under these circumstances it is the province of a technical paper to give its readers an accurate and extended account of the subject, but unfortunately the restrictions in this instance are of such a nature that only a general picture of the fundamental principles can be given.

It is but a short time since the adoption of magazine and rapid-fire guns was a burning question, and in a certain sense it is yet an open one, but still the powers have equipped their armies with rifles of one-third less caliber than those formerly in use, in order that the already heavily burdened soldier may carry a greater number of rounds of ammunition. This change in caliber necessitated, from the outset, a change in the powder charge, for it was essential that the bullet should have an equal range. Next, as owing to the rapid fire but little time was allowed for aiming the piece, it became essential that the projectile should have a very flat trajectory. This pointed to the use of a very *brisant* powder; but as this would necessitate the use of a very strong piece to resist successfully the suddenly developed pressure, it was agreed that new powder must be less *brisant* and should develop its full power at the muzzle of the piece, giving a high initial velocity with a low pressure.

These conditions obtain equally for small arms as for great guns, but the further development for the two classes is different and the powder problem becomes unlike for the two. Hence, when speaking to-day of the smoke-weak powders we refer principally to the small-arm powder.

Although at the outset it was sought to satisfy these requirements by changes in the composition, method of treatment during manufacture, and in the form of the cartridge, a fresh difficulty was soon

encountered. Even before this "an atmosphere filled with powder smoke" had been no empty phrase, but with the rapid-fire guns it was found that the smoke would be increased so as to be insupportable, and that even the skirmisher would be so enveloped, after a few rounds, especially in calm weather, he would be unable to take aim. Hence a powder had to be invented which burned without smoke, and since this, while theoretically possible, was not so in practice, the powders of this class which appeared were first styled in Germany smoke-feeble powders (*rauchschwaches Pulver*).

From the preceding it appears that the smoke-feeble powder should satisfy the following requirements:

1. High power in a small space.
2. Low specific gravity (to produce a light cartridge).
3. Low gas pressure.
4. High initial velocity.
5. Great flatness of trajectory.
6. Small development of smoke.
7. Harmlessness of the smoke.
8. Constancy.
9. Safety in handling.

The eighth point demands a thorough discussion, for under "constancy" is to be understood a number of conditions.

We shall see later on that the smoke-weak powders principally belong to the class erroneously styled chemical explosives. The readiness with which such substances are resolved by explosion into their constituents throws a doubt on their constancy under all conditions, and their permanency must be proven under all the extremes of heat and cold, dampness and dryness, blows and shocks, agitation, exposure and the like, which obtain in practice. Again, the tendency, such as has been observed in the black powder, to separate into its constituents when moist must be provided against. No mildew should form upon them as does form on gun-cotton. They should have no action on the walls of the cartridge cases. They should be so insensitive to mechanical influences that they will withstand careless handling in the field.

In seeking for the ideal smoke-feeble powder it was but natural to turn to nitrocellulose. Already for many years wood nitrocellulose, known as Schultze powder, has been employed in England for sporting purposes, and this was followed by E. C. powder,* which

* *Ding. Poly. Jour.* 249, 456; 1883.

consisted principally of gun-cotton; while more recently a number of other gun-cotton powders have been noticed, principally for use as sporting powders, but were introduced into use only with great difficulty, and the sporting-paper *Field* had frequently to recount accidents caused through the bursting of the pieces.

Owing to the increasing use of gun-cotton for filling torpedoes and shell, the process of manufacture has been so perfected as to yield an explosive whose properties can be maintained nearly uniform. At the same time, owing to melinite, attention has been called to picric acid and its derivatives, and these have been more thoroughly studied.

The use of gun-cotton proper (trinitrocellulose) could not be thought of, owing to the *brisant* action of this body, but it was found that collodion-wool (dinitrocellulose, soluble gun-cotton), which was less *brisant*, could be converted into a nearly homogeneous mass which satisfied many of the requirements of a smoke-feeble powder, but it was still so *brisant* when used alone as to produce too high gas pressures and too irregular initial velocities. Hence the more successful recent powders consist of soluble gun-cotton mixed with other substances which diminish the *brisant* effect, or it is treated in a particular manner to produce the same result. Thus Wolff & Co., in Walsrode, who have been treating gun-cotton for use in shell charges* in a similar manner, treat the collodion-wool with acetic ether, and the thin skin of collodion thus produced retards the rate of burning. A similar process is employed by H. S. Maxim, of London,† who conducts the vapor of acetic ether to the gun-cotton, and when action has taken place, forces the plastic mass through holes into strips, which are then cut into smaller pieces.

Fr. Gaens, in Hamburg (under which name some expect to find the powders produced by the Rottweil-Hamburg factory), dissolves nitrocellulose in acetic ether to form a gelatinous mass, and mixes with 25 parts of the nitrocellulose, 60 parts of potassium nitrate, and 15 parts of ammonium humate (obtained by treating peat with lye); the mixture being then pressed, granulated and dried.

The Nobel smoke-feeble powder‡ was originally a modification of the camphorated blasting gelatine, but it was found that the camphor was unreliable and required a special purification to secure uniform results. At present, according to private information, this

* Proc. Nav. Inst. 11, 112; 1885.

† Ding. P. J. 272, 66; 1889.

‡ Ding. P. J. 273, 67; 1889.

powder consists of 50 parts of nitroglycerine and 50 parts of collodion-wool. It is impossible to produce a gelatine containing so large an amount of nitrocellulose directly, so benzol, in the required proportions, is mixed with the nitroglycerine, and these are sprayed in fine streams on the nitrocellulose. The mixture, after evaporation of the benzol, is then rolled into sheets which are cut into strips and grains. The sheets have a dark brown color and resemble caoutchouc. The powder is more yellow-brown. If a sheet is ignited it burns in layers and emits sparks.

It is interesting to note that in the case of the Nobel powder, nitroglycerine, which is one of the most powerful explosives, is used mainly to diminish the *brisant* effect of the collodion-wool, and also that it does not detonate even under the influence of the primer of the rifle. The impediments which prevented the production of perfectly uniform gelatine are inherent in the manufacture of this powder, and this lack of reliability is no doubt the reason why this smoke-feeble powder, which otherwise possesses so many excellent qualities, has not come into use.

Abel and Dewar are reported to be engaged in perfecting the gelatinization process for the English government, and in manufacturing a powder which is said to have given excellent results. This new powder, called Cordite, is brown in color, and is in the form of cords of the length of the cartridge, which are bundled like fagots.

The Swiss government have already introduced a smokeless powder, P. C. 88 (Powder Composition 88), made by Schenker and Amsler Sohn, which gave with a charge of 2.4 grams in the 7.5 mm. Schmidt rifle an initial velocity of 615 m., with a maximum pressure of 1300 atmospheres.

France has for some time possessed the smokeless powder produced from collodion-wool by Vieille. Austro-Hungary seems recently to favor the powder of Major Schwab, which is described as a dark-gray, coarse-grained chemical product. Belgium is engaged in the production of wood-nitrocellulose. Germany, which has perhaps made the largest number of trials of private powders, is said to have declined to accept any powders produced by private firms, and to have recently rejected a large lot for failing to meet the requirements and for lack of sufficient stability. It is believed that Germany possesses in the powder manufactured by Major-Gen. Küster, at Spandau, an excellent shooting agent.

In general it may be said that no perfect smoke-feeble powder has

yet been invented, each of those known having its weak points, and therefore those governments that are not directly menaced are disposed to await further developments.

Picric acid and its congeners play an important role in cannon powder. It is yet too early to treat of this, because very sensible irregularities are observed in the composition for large charges, and up to the present nothing really good is at hand. In general, gun-cotton, ammonium picrate and fused picric acid are preferred for projecting and bursting charges.

Since the patents of the different factories seem to conflict, and the different smokeless powders have much in common, some of the German manufacturers have combined with Nobel, by which all are protected, and through their co-operation *one* satisfactory powder may be obtained.

In the *Journal of the Royal United Service Institution*, London, July, 1891, p. 707, is a paper by Lt. Col. G. V. Fosbery, in which, after referring to the historical development of the magazine gun, he continues as follows in regard to the ammunition which they carry: "Side by side with the change of weapons, a no less important one has been made in the ammunition they carry. That such should have been the case is but the logical consequence of the adoption of the repeater. From the moment this was decided on, it was seen that, in the first place, it would be desirable to reduce the size of the cartridge so as to maintain the handiness of the weapon; and, secondly, to reduce its weight in order that the soldier might carry a larger number—wrongly or rightly supposed to have become an absolute necessity.

"To reduce the *size* of the cartridge, the space occupied by the charge must be diminished, and for this either the present charge must be made to occupy a smaller space, or a more energetic explosive be found. We are thus at once compelled to use either compressed gunpowder, or one of the higher explosives.

"Again, to take largely from the weight, the bullet must be lightened; and here we must be careful. The range of artillery is increasing every day, and the bringing of quick-firing guns into the field is but a question of time. The infantry cannot afford to lose a yard of their range. The sectional density of the bullet cannot, therefore, be lowered—nay, rather needs increasing—and the reduction in weight must be effected by a diminution of caliber.

“Many of us were in hope that this would go no further than to 0.400 inch or 0.380 inch, when a plain hardened bullet could have been used, and a very considerable economy in the price of ammunition been effected. When, however, it came to be seen what velocities, range, and penetration could be got with a thing like this, no bigger than a common pencil-case, the caliber of 0.303 was decided on, and with it, as a consequence, the metal envelope, regarding the cost and other difficulties of which so much has been said. The studies of Hebler and Guillaumôt, and the practical experiments of Lorentz prepared the way for this or even a greater reduction of caliber; so that, in theory, no risks of mistake were run.

“It may be an open question whether or no at extreme ranges the fire of the new magazine gun will be as fatal as is that of the Martini-Henry, and whether it would be possible with it to inflict on a distant enemy such terrible losses as fell upon the Russian columns in the valleys near Plevna from Turkish unaimed high-angle fire. We all know that a very small and light bullet, having a speed of 1600 feet per second or over, *i. e.* a bullet traveling at so-called *express* speed, will smash bones and tear up and pulverize flesh in a way totally different from the behavior of the same bullet endowed with a lower velocity, and it may prove to be the case that beyond certain ranges, the effects of the new projectile, say on supports and reserves, will be less than those of the heavy Martini bullet in a very notable degree. As, however, we are promised an initial velocity of something approaching 2000 feet per second, no doubt we shall have an extremely flat trajectory and deadly effects for a very considerable distance, and in any case what is true of our own bullet will—so nearly alike are they—be true of every other bullet in Europe.

“At present, so far as is known to me, we are still in search of the ideal explosive; one, in fact, which shall pack into the smallest possible space, develop the utmost energy, and keep indefinitely under all possible circumstances, and until we have found this, or at all events some reasonable approach to it, we cannot with a light heart adopt, as our Continental friends have done, a smokeless powder for the use of our troops. Gunpowder we know all about; it is a good honest mixture, and, sorely tried as it frequently is ashore and afloat, it may be always reckoned on to do its duty so long as we keep it dry. But when we come to high explosives—specially when these are chemical compounds, and from their very nature more or less unstable compounds at that—we, more than any other people, must

exercise the utmost precaution in their general adoption, and be sure that neither the damps and heats of India, the salt air in our naval magazines, nor the cold of Canadian winters, will set these treacherous substances fermenting, decomposing, or exploding. Hitherto perhaps on the whole Professor Abel's powder, cordite, has shown the best all-round qualities, and bids fair for final selection.

"Having thus spoken of the ammunition question, which will, I believe, when fully settled, effect a more marked change in the conditions of war than even the adoption of the magazine gun, I will, if you please, return to the question of the latter."

U. S. Letters Patent No. 456,508, July 21, 1891, have been granted Alfred Nobel for an Improved Celluloidal Explosive and Process of Making the Same.

It is known that the gelatinous compound commonly called "blasting gelatine," and patented by him in 1876, is composed of nitroglycerine and soluble nitrocellulose, the proportions adopted in practical use being from five to seven parts by weight of the nitrocellulose, to from ninety-three to ninety-seven parts of nitroglycerine, to which is added a small portion of nitro-benzol or analogous matter when it is desirable to make said jelly less sensitive to concussion or percussion. This compound, owing to its eminently detonative character, has been extensively used for blasting rock, but has proved altogether too violent in its action for use as a propeller for projectiles.

The object of the present invention is to so modify the explosive character of this compound as to produce from the same materials an essentially new article possessing the progressive explosiveness needed for propelling projectiles. This he effects by employing a process enabling him to incorporate with nitroglycerine a quantity of soluble nitrated cellulose 10 to 20 times greater than that which is contained in his "blasting gelatine," thereby producing a substance which, in its physical aspect as well as in its intrinsic explosive properties, differs widely from the "blasting gelatine," inasmuch as through the horny or celluloidal character which it assumes it is capable of being reduced to so-called "grains" akin to those of granulated gunpowder.

In manufacturing his present explosive, he dissolves in 100 parts, by weight, of nitroglycerine, say 10 to 15 parts, by weight, of camphor, adding thereto as a diluent, say 50 to 100 parts, by weight, of

benzol. To this mixture is added, say 100 parts by weight, of dried, pulped, carded, soluble, nitrated cellulose, such as nitrated cotton fiber. He then mixes the materials until the nitrocellulose has completely absorbed in its pores the aforesaid liquid and until homogeneity is secured. This done, the benzol is evaporated in the open air, or, better, in a closed chamber provided with a cooled condenser, for the purpose of recovering the benzol or the greater part thereof. When the benzol is evaporated, the material thus obtained is passed for malaxation between steam-heated rollers, when it assumes the aspect and consistence of a somewhat soft celluloid. It is then ready to be rolled out into sheets of any required thickness. These sheets he converts into "grains" by cutting them up into cubes or small pieces of any desired shape, which reduction serves the same purpose as granulation for gunpowder.

The addition of benzol, for which may be substituted any other volatile substance having the same property of mixing with nitroglycerine and rendering nitrocellulose insoluble therein, serves no other purpose than to facilitate by such insolubility the equal absorption and distribution of the liquid into the fibers of the nitrocellulose. As soon as the benzol has been evaporated the nitrocellulose begins to dissolve, and when dissolved the compound is treated as already described.

The given proportions of the ingredients are not absolute, but may be varied in a wide measure, the limits of which will be determined by the facility or resistance which the compound offers to its reduction into "grains." Thus if the celluloidal substance contains more than 2 parts of nitroglycerine to 1 part of nitrocellulose, it becomes almost too soft for a substance which has to be used in a granular form; and if it contains as little as 1 part of nitroglycerine to 2 parts of nitrocellulose, the celluloid obtained is more stiff and hard than needed, and is less easy to manufacture than such celluloid containing no more than half its weight of nitrocellulose.

When the celluloidal substance is made to contain more than half its weight of dissolved nitrated cotton fiber, its formation in the manner described becomes somewhat troublesome, in so far as it requires a prolonged malaxation between steam-heated rollers, or similar treatment. In such case he prefers the substitution for benzol of a volatile substance, such as acetate of amyl, or of ethyl or acetone, wherein the nitrocellulose is soluble, and wherewith the nitroglycerine is miscible, and he adds of such solvent the quantity

needed for complete incorporation of the ingredients ; the proportion depending on the solvent's volatility and the temperature at which the malaxation is effected ; but there is no mistaking in practice the proportion needed, since sufficient of the solvent must be added to obtain a translucent celluloïdal substance. Moreover, for practical use the above given proportions of equal parts of nitrocellulose and nitroglycerine plus camphor gave an excellent result, so that the addition referred to of an excess of nitrocellulose, necessitating an extra addition of solvents, will be resorted to only in exceptional cases.

The nitrated ingredients used are to be deprived carefully of adhering acids by proper methods of washing.

Solid powdered substances may be kneaded in by malaxation between steam-heated rollers or otherwise, and the explosive celluloïd may be mixed with pulverulent explosives, such as nitrated starch, nitrated dextrine, mealed gunpowder, or picrates ; but it may also be mixed, and this is of importance with powdered oxidizers, such as nitrates or chlorates, for the purpose of furnishing the oxygen wanting for complete combustion, and with a view to reduce the cost price of the article.

The celluloïdal explosive composed of 100 parts of nitroglycerine, 100 parts of nitrocellulose, and 15 parts of camphor, contains approximately the oxygen needed to convert, by explosive combustion, all its constituent hydrogen into water vapor and all its carbon into carbonic oxide ; but to obtain complete combustion and thereby to convert said carbonic oxide into carbonic acid, it would be necessary to incorporate with each 100 parts of the compound about 82 parts of nitrate or chlorate of potash, or 69 parts of nitrate of soda, or 100 parts of nitrate of baryta, or 163 parts of nitrate of ammonia, or 96 parts of perchlorate of ammonia.

Bearing in mind that one part of hydrogen requires for its combustion eight parts of available oxygen, and that each six parts of carbon require for transformation into carbonic oxide eight parts, and for forming carbonic acid sixteen parts of available oxygen, it is easy to calculate the proportions of oxidizing nitrates or chlorates suitable for each particular case, it being understood that the quantity of oxidizers added should not exceed that needed for complete combustion. Also, the quantity of powdered oxidizers which can be added is limited by the capability of easy practical incorporation by malaxation. The more nitroglycerine and the less nitrocellulose it contains,

the more soft and plastic the explosive celluloid becomes, especially when heated, and the greater will be the proportion of powdered substances which can be practically incorporated.

The camphor or other predisposing solvent may be partly, and even almost entirely evaporated without very materially altering the explosive properties. Such evaporation can be effected by long exposure to the air at the ordinary temperature; but it is much quickened by letting a current of air heated to, say 50° C., percolate among the "grains" of the powder. Of course such evaporation reduces the amount of carbon and hydrogen, so that if oxidizing nitrates or chlorates be incorporated with the explosive, their quantity should be proportionately reduced.

This explosive celluloid can be used for blasting rock, in which case the "grains" may be compressed, similarly to gunpowder, so as to form cylinders or pellets suited for miners' use. Such compression may either be effected at a temperature (60° to 80° C.) at which the material becomes sticky, or at the ordinary temperature by slightly moistening the grains with a solvent, such as acetone or an acetic ether. Of course the grains should not be compressed so much as to leave no air space, upon which the quick spreading of the flame depends. The aforesaid powder can be fired without a detonator, thereby completely differing from the so-called "high explosives" now in use.

Whether for blasting or propelling purposes this explosive has always to be used in a granulated state, or so divided as to present a sufficiently large surface for combustion. The size of the grains or particles varies for each caliber of arms and other varied conditions, as is likewise the case with gunpowder; but otherwise the mode of using and firing does not materially differ from that explosive, except as regards suiting the charge to the ratio of power.

He claims:

1. A process for forming hard celluloidal explosives for propelling or filling projectiles, or for blasting purposes, which consists in uniting nitrocellulose and nitroglycerine, in proportions substantially as set forth, by means of a volatile solvent, as acetone, camphor, or the like, and subsequently removing said solvent, and mechanically treating the same, substantially as specified.

2. The hard, horny, or celluloidal explosive in granular form for above purposes, containing nitrocellulose and nitroglycerine, the same being so far solid at ordinary temperatures as to be susceptible of being cut up into so-called "grains."

3. The cellulosidal explosive above described, in dense, horny, granular form, solid at ordinary temperatures, composed of nitro-cellulose, nitroglycerine, and suitable oxidants, as specified, and adapted for propelling or filling projectiles, or for blasting purposes.

The following "Experiments to Determine the Liability of Cordite to Explode *en masse*" were carried out on Woolwich marshes on the 21st of October, 1890, by the War Office Chemical Committee on Explosives, in the presence of the Director General of Ordnance Factories, H. M. Chief Inspector of Explosives, and other officers.

1. 100 lbs. of coarse cordite (3 in. diameter and 14 in. in length), packed in a service box (measuring 2 ft. 3 in. \times 14 ft. 6 in. \times 7 ft. 9 in. deep, and having $1\frac{1}{4}$ in. sides and 1 in. top and bottom), was attempted to be ignited by means of a tube and small priming charge of gun-cotton. But the cordite failed to ignite.

2. Repetition of above, but using a small priming charge of fine cordite (.05 in. diameter and 11 in. long). The whole mass burst immediately into flame, and burned with great and rapid energy and brilliancy. The lid was removed by the energy of the outburst, the screws being drawn, and those on one end bent. The mass burned for about three seconds, and the light was of the most brilliant character.

3. Repetition of No. 1, and with same result. No ignition.

4. Repetition of No. 2. The cordite ignited and burned with great brilliancy and a gush of bright flame for about $7\frac{1}{2}$ seconds. The lid of the box was forced off (as in No. 2), and the screws were drawn, and in some cases bent.

5. A service case (of dimensions previously given) containing 100 lbs. of the fine cordite was surrounded by wood and shavings, which were set fire to. The bonfire burned for 15 minutes, when the cordite in the case ignited and burned, with a great rush of most brilliant flame, for about four or five seconds. Some small pieces of the burnt wood were then thrown to a distance of about 12 yards. An end of the box was forced out. One side was partially forced out.

6. Repetition of No. 5, but using fine instead of coarse cordite. After the bonfire had been burning for seven minutes the cordite caught and went off with a dull, muffled burst which nearly amounted to a mild explosion. There was, however, certainly nothing approaching a violent explosion, as was shown by only one side of the box being displaced.

7. Six service boxes containing each 100 lbs. of thick cordite were placed together, five on end and one on the top; the center box (in lower tier) was set fire to. It burned about six seconds, and upset the side boxes, but it did not throw off the top box; only the box which was ignited caught fire.

8. Five service boxes each containing 100 lbs. of thick cordite (*i. e.*, those which remained from the last experiment) were placed in a pile, two, two and one, breaking joint; and surrounded by wood and shavings, which were set fire to.

After 15 minutes,				1 box of cordite ignited.			
"	15	"	7 seconds,	1	"	"	
"	15	"	14	"	1	"	"
"	15	"	21	"	1	"	"
"	15	"	28	"	1	"	"

Each box burned with a bright rush and burst of flame, but without explosion. The boxes were not broken up, and no fragments of the bonfire were projected beyond about 10 paces.

9. A pile of eight service boxes containing each about 75 lbs. (total 600 lbs.) of cordite was surrounded with wood and shavings, which were set fire to. The top box had a hole in it, which was roughly plugged, and this apparently caught fire and burned away non-explosively at 1 min. 10 secs. after the bonfire had been ignited. The other boxes ignited in succession and burned away non-explosively. The times were as follows:

	Min.	Secs.		Min.	Secs.
1st box,	1	10	5th box,	17	25
2d "	1	15	6th "	18	37
3d "	2	2	7th "	21	31
4th "	5	45	8th "	21	33

—15th *Ann. Rept. H. M. Insp. Exp.* p. 80, 1891.

C. Roth, Eng. Pat. 858, Jan. 16, 1890, for "Improvements in the Manufacture or Separation of Ammonium Nitrate and Sulphate or Chloride of Sodium and of Potassium," prepares ammonium nitrate from equivalent quantities of ammonium sulphate and potassium or sodium nitrate, either by heating the aqueous solution of these salts or by melting them at a temperature below that at which ammonium nitrate dissociates. If the aqueous solution be heated to a temperature above 110° C. until practically all the water is driven off (110° C.

being the temperature at which a solution of ammonium nitrate in an equal weight of water boils), or when the salts are heated in the absence of water and the melt maintained at a temperature between 160° and 200° C., sulphate of potassium or sodium, as the case may be, separates out in the solid form and settles to the bottom of the melt, whilst a liquid layer of ammonium nitrate remains above, which can be easily siphoned off or otherwise removed. A solution of ammonium in an equal weight of water, at a temperature of 110° C., is only capable of holding in solution 15 per cent of sodium sulphate and 10 per cent of potassium sulphate, and the solubility of these substances in ammonium nitrate decreases as the temperature is raised, until at 200° C. (at about which temperature ammonium nitrate decomposes) only traces are held in solution. Ammonium chloride may be similarly used instead of ammonium sulphate, but its greater cost makes it less advantageous.

C. Roth and W. J. Orsman, Eng. Pat. 20,104, Dec. 13, 1889, for "Improvements in the Treatment or Preparation of Nitrate of Ammonium," proceed as follows: To prevent the absorption of hygroscopic moisture by ammonium nitrate, the crystals of that salt are dried by heating to 80° C., and a solution of nitrocellulose "in the various nitro- and chloro-nitro compounds of benzene or of the benzene series of hydrocarbons and their derivatives" is then poured over them, the mixture thoroughly stirred and allowed to cool. This treatment is especially advantageous when the ammonium nitrate is used in the manufacture of explosives.

To Paul Ward and Edward Mammatt Gregory have been granted U. S. Letters Patent No. 454,239, dated June 16, 1891, for the adaptation of a "Composition Suitable for Priming," to the purposes also of detonation, by the addition of a further ingredient to the composition, thus providing a novel, cheap, and effective detonating material, and manufactured at a minimum risk, suitable for use in any fuse or for similar purposes.

They form the chief basis of their explosive composition by the admixture of powdered coke, 2 pounds; amorphous phosphorus, 1 pound; pure chlorate of potash, 75 pounds, with the addition of benzol, chloride of carbon, or acetate of amyl. The amorphous phosphorus and chloride of potash are ground separately in a mortar or other vessel under one of the above fluids. The amor-

phous phosphorus is then submerged with either of the above fluids. Chlorate of potash is then added and the two ingredients are ground together under sufficient fluid to keep the mass from clogging. When this has been done for a suitable time, coke is added in powder and the whole is again ground for a short time. This forms an excellent priming composition, and by the addition thereto of paraffine or common tallow oil the powder will be enabled to cake together after the grinding fluids have evaporated. This reduces its sensitiveness to friction or percussion without detracting from its explosive violence or its sensitiveness to an electric current, and thus constitutes an excellent detonating composition.

They have found that the detonating effects of this compound are most pronounced when it is detonated by the previous explosion of a priming composition occurring at the closed end of a fuse and detonator-case, where the compression of the gases from the exploding priming composition causes intensely rapid combustion and consequent detonation in the detonating charge.

They state the manufacture, as described, to be much less dangerous than where the usual fulminate of mercury is employed, and that the addition of paraffine oil to the composition serves also to prevent oxidation of the ingredients when stored.

They claim a detonating composition consisting of powdered coke, amorphous phosphorus, chlorate of potash, and paraffine oil, substantially as and for the purpose set forth.

U. S. Letters Patent No. 455,332, July 7, 1891, have been granted Joseph A. Hunt, for a "Blast Cartridge." The invention is described as consisting of two parts of a cylinder, which are hollowed out in their middle so that when they are placed together a recess is formed for the reception of the explosive which may be used. These two parts have each in one end a perforation for the insertion of a fuse, and are made with longitudinal and abutting flanges, which, when the explosive is ignited, permit of the two parts flying apart in opposite directions, thus splitting the log, rock, or other analogous substance asunder. It is said that in using this cartridge no tamping is necessary, that a wet log can be split as easily as a dry one, and that this method of blasting is less dangerous than the old methods, in that the cartridge will not jump out of the log when fired. He claims as new the two halves of a cylinder, recessed as above described, each possessing longitudinal and abutting flanges, with a perforation at the end of each for insertion of a fuse.

Commander F. M. Barber, U. S. N., has been granted U. S. Patent 435,788, Sept. 2, 1890, for a "Method of Floating Stranded Vessels," in which, after pointing out that while one hundred pounds of gun-powder or thirty pounds of gun-cotton will infallibly blow a hole in the side of a ship with which it is in contact, yet at a distance of twenty-five feet horizontally, or ten feet vertically, a vessel using such a torpedo will, while receiving a heavy shock, remain entirely uninjured, he claims: The method of floating a stranded vessel or other object by exploding torpedoes or like agents beneath the surface of the water in the vicinity of the same, thereby causing a shock or concussion and at the same time exerting traction thereon, as by hawsers, from a point outside the vessel, substantially as described.

Under the title "Outbursts of Gas in Metalliferous Mines," B. H. Brough gives, in the *School of Mines Quarterly*, **12**, 13-22; 1890, an account of a number of cases in which gas has been liberated in metalliferous mines, and in some of which serious explosions have occurred. He shows that these outbursts of gas are not always due to the same cause, and he gives the following explanation to account for the formation of the gas in the various cases described: 1. The decomposition, in a mine, of timber in contact with water or moist air may produce fire-damp, which would accumulate in cavities that are ultimately broken into. 2. In iron mines when the iron is not entirely in the state of peroxide, water might be slowly decomposed and hydrogen produced. 3. Fire-damp may be liberated from beds beneath the ore-deposit and find its way through fissures into the workings, the gas being given off from rocks enclosing bitumen in the same way as the natural gas of the United States and other countries. At some of the Derbyshire mines the gas is derived from the Lovedale shales, which are of a bituminous character. 4. Fire-damp may be produced from the decomposition of organic matter in the same way as the hydrocarbon met with in salt mines. 5. In some cases explosions have been caused by outbursts of sulphuretted hydrogen produced by the action of acid waters on pyrites ore. 6. The outbursts of carbon dioxide met with at Foxdale, Freiberg, and Massa Maritima, may have been caused by the action of acid water, produced by the oxidation of pyrites, on limestones and other metalliferous carbonates.—*Jour. Soc. Chem. Ind.* **10**, 143; 1891.

An explosion, which in many of its features recalls those of Rochester and Pawtucket,* occurred in Providence, R. I., Sept. 5, 1891, and resulted in fatal injuries to one man, severe to two others, and slight injuries to several others. From the description in the *Prov. Journ.*, Sept. 6, 1891, we learn that private parties have a contract with the city for the disposal of its swill; that as a step in this process the grease is extracted with petroleum-naphtha; that this naphtha is brought once a month in tank cars holding 7000 gallons each; that this naphtha is conveyed from the cars, through a two-inch pipe, 500 feet long, to the works; that on the day of the accident a leak was discovered in the pipe leading from the naphtha tank by which naphtha escaped to the river, and that immediately on discovery the hole was plugged. It was not supposed that any considerable amount of naphtha had escaped, yet, within a few minutes after the hole was stopped, a report was heard from the Woonasquatucket river, and a sheet of flame, followed by a dense cloud of black smoke, was seen to be projected to a considerable height above it. It was found that a pile-driver had been at work in the river, and that the vapor from the naphtha floating by the scow had become ignited at the fire under the boiler.†

The *N. Y. Herald* of Oct. 16, 1891, details the circumstances attending an explosion on board the U. S. S. Atlanta, Oct. 13th, while at sea in a gale of wind, from which it appears that the forward collision compartment being found filled with water through a leak in the hawse-pipe and imperfect closing of the forward hatch, a handy billy was rigged to pump it out, and when after some hours the suction failed, an ordinary lantern was lowered into the compartment to ascertain the cause, whereupon an explosion ensued which resulted in severe injuries through burns to two men, and more or less serious ones to four others, while the collision bulkhead was markedly bulged. A board ordered, of which the writer was a member, found that the collision compartment had been used as a store-room for paint stores in their original packages, and that among them were spar and damar varnishes and Japan dryer, each of which gave off vapors at ordinary temperatures, which formed easily exploded mixtures when diffused through the air, and that this mixing was more readily effected by agitation with salt water under the conditions which prevailed on the Atlanta.

* *Proc. Nav. Inst.* 14, 165-166; 1888.

† *Ibid.* 20, 291; 1889.

The explosion and fire which occurred June 15, 1891, in compartment No. 73 of the U. S. S. Philadelphia, were traced to a similar source, and the analogy to the Doterel* accident and similar ones pointed out. (*N. Y. Tribune*, Nov. 27, 1891.)

In consequence of this report, the *Brooklyn Union* of Nov. 11, 1891, states that the Secretary of the Navy has issued an order amending paragraph 34 of page 39 of the Regulations of the Navy to read as follows :

“Spirits of turpentine, alcohol, all varnishes and liquid dryers must be kept in metallic tanks or vessels securely stowed away on the spar deck, and they are never to be taken below except in small quantities for immediate use.”

According to the *N. Y. World*, Oct. 27, 1891, an explosion of a similar nature occurred at No. 69 Pineapple street, Brooklyn, N. Y., Oct. 26, through which a young girl was seriously, and perhaps fatally burned. It has been found that petroleum-naphtha or benzoline is a most efficient agent for the destruction of moths, and it is a not infrequent occurrence in establishments where furniture is treated, that, since the fabric is not affected by the naphtha, lounges, mattresses, arm-chairs and the like are completely immersed in the liquid, and retained until saturated.

In this instance the upholsterer employed sought to destroy moths which had gotten into the furniture, and to arrest and repair their ravages, but he endeavored to do this by sprinkling the furniture with naphtha, and closing the doors and windows of the room in the dwelling-house in which the articles were. Some time later the child returning from school opened the door between the room with the naphtha-laden atmosphere, and an adjacent one in which a fire was burning in a stove, when the vapor at once ignited and flashed back.

In the *Sci. Am. Sup.* 32, 13053; 1891, under the title of the Spontaneous Ignition of Carbon Bisulphide, Dr. Max Popel states that in view of the widespread application of carbon bisulphide in extraction processes, and of the frequent explosions and fires which are caused by its spontaneous ignition—*i. e.*, without its actually coming in contact with flame or any red-hot substance—it is of interest to collect and publish all the observations which have been made concerning the causes of such accidents.

* Proc. Nav. Inst. 8, 313; 459; 671; 1882.

Unfortunately, the nature of carbon bisulphide is by no means thoroughly known; in particular we have no complete data as to its behavior at different temperatures and pressures, mixed with other gases, air, etc., in contact with metals and other substances; and yet a knowledge of these very points is necessary before the substance can be employed with safety. The main difficulty to be met with in the employment of carbon bisulphide is its volatility. Even at a very low pressure (0.1 atmosphere and less) it is quite impossible in an extraction apparatus to prevent its escape by means of taps and the like. Again, the air which is always admitted on filling the apparatus is again drawn out, saturated with the vapor, the loss increasing with the temperature. In the course of some experiments instituted to ascertain the actual amount of material carried away by the air, a spontaneous ignition of carbon bisulphide was observed under the following circumstances: The tube which connected the interior of the apparatus with the air, and which had previously ended near the roof of the building, was bent over and the end allowed to dip about 10 centimeters into a vessel filled with oil. It was found that the oil absorbed the carbon bisulphide almost completely, and that the whole loss, at the temperature of the cooling surface (10° – 12° C.), was only very small; but that it amounted to several liters in the course of a very few hours at a temperature of 8° – 10° above this. A pressure of about one-eighth of an atmosphere was also set up in the apparatus, owing to the descending path which the air had to take, and to the pressure of the oil, and this, of course, affected the boiling of the carbon bisulphide. In order to remedy this, the apparatus was to be removed and replaced by another arrangement. While a workman on the roof was screwing off the descending arm of the pipe, Dr. Popel stood by the oil flask, which was perfectly cold, as was also the pipe dipping with it, and in order to allow a little more room for the motion of the pipe, he placed the flask at a lower level, when just at that moment the workman informed him that the pipe was beginning to get very hot at the joint. He was about to quit the place and see for himself if this were correct, when an explosion took place in the apparatus, and the oil saturated with the carbon bisulphide took fire. In this case, therefore, the spot at which the ignition started could be determined with a certainty which is rare in accidents of the kind. No external influences were possible, and the idea that the explosion was caused by the absorption of oxygen by the oil and consequent heating is disproved by the fact that the whole remained

quite cool until the actual moment of ignition. The only probable explanation is that the mixture of carbon bisulphide and air was raised to its igniting point by the heat developed in the pipe by the friction at the bend which was being unscrewed. The pressure being diminished by the lowering of the vessel, the flame spread downward and ignited the oil. The actual temperature attained in this case could not be ascertained, but the following experiment shows that carbon bisulphide and air will ignite even below the boiling point of water. A watch-glass containing carbon bisulphide was placed in a new copper oven with smooth walls; explosion took place regularly at 96° – 98° ; when the walls were covered with a layer of clay this no longer occurred, so that copper seems to have played an important part in the phenomenon. Mixtures of carbon bisulphide and air readily ignite when brought in contact with iron pipes through which steam at 3 to 4 atmospheres (135° – 145° C.) is passing. The less carbon bisulphide there is in the mixture the higher is its ignition point and the sharper the explosion.

It is, therefore, necessary, in places where this substance is employed, to cover all steam pipes, cocks and valves with great care, and also to work without any pressure, so as to avoid loss. Unfortunately it is impossible to employ the vacuum, since the escape of the vapor into the pump cannot be avoided, and explosions would be caused by compressing it when mixed with air.—*Chem. Zeit.*

T. E. Thorpe describes in *J. Chem. Soc.* **55**, 220–523; 1889, a lecture experiment on the “Decomposition of Carbon Disulphide by Shock.” The apparatus consists of a thick glass tube about 600 mm. long and 15 mm. wide, fitted at one end with a caoutchouc cork, through which pass two stout wires or thin rods. A small brass or iron cup, like a deflagrating spoon, is attached to one wire, and the other wire is bent so as to come within 2 to 3 mm. of the bottom of the cup. About 0.05 gram of mercury fulminate is placed in the cup, the cork is fixed tightly into the tube, which is clamped to a retort-stand and tilted to an angle of 45° ; and a piece of paper which is slightly longer than the tube, and which is moistened with carbon disulphide, is placed within the tube, where it remains for a minute or so, when, the tube being practically filled with the vapor of carbon bisulphide, it may be withdrawn. On now passing a spark from a Ruhmkorff coil through the cup, the fulminate will be detonated and will detonate the disulphide, and the internal walls of the tube will become lined with a deposit of soot mixed with mercuric sulphide and

free sulphur. Similar effects are obtained by filling the tube with a mixture of carbon disulphide vapor and nitrogen or carbon dioxide, but in these cases the deposit of carbon is comparatively dense, lustrous and coherent. This forms an easy and safe method for demonstrating the resolution of an endothermic compound by shock.

Dr. Thorpe was led to devise this experiment through an observation made while investigating the sulphides of carbon. Löw had obtained the C_2S_3 by the action of sodium amalgam on CS_2 , and Raab had obtained C_5S_2 by the action of sodium alone on CS_2 . Dr. Thorpe used the fluid alloy of sodium and potassium, and treated rectified, dehydrated CS_2 with this alloy, when, after a few hours' standing, the alloy was seen to be incrustated with a yellowish-brown powder. On now shaking the bottle to detach the crust, the contents exploded with a loud report, and the operator's hand was coated with a black deposit consisting, apparently, of finely divided carbon. Further experiments showed that the yellowish-brown powder was highly explosive, and that on simply pressing with a glass rod it detonated with even more violence than nitrogen iodide.

He is as yet only able to offer conjectures as to the nature of this powder. It may be a compound of carbon monosulphide and potassium, analogous to that formed by carbon monoxide and potassium.* There is some ground for the belief that the highly explosive character of the latter substance is really due to the formation of potassium acetylide, produced by the action of moist air upon it, for it is well known that when thrown into water it detonates with great violence and with the evolution of acetylene. In the case of the compound formed by the action of carbon disulphide there can, however, be no suspicion of the presence of hydrogen.

Attempts were made to effect the decomposition of the CS_2 by the use of other explosive agents than the yellowish-brown powder and the fulminates, gunpowder, potassium chlorate and phosphorus, potassium chlorate and ammonium picrate, copper acetylide, nitrogen iodide, Berthollet's silver amine, oxygen and hydrogen, and oxygen and carbon disulphide vapor being used, but they had no apparent effect.

In an article on the "Formation and Decomposition of Carbon Disulphide," *Compt. rend.*† 67, 1251; 1869, Berthelot calls attention

* Proc. Nav. Inst. 12, 190-193; 1886.

† Bull. soc. chim. 11, 45; 1869. Chem. Centr. 333; 1869. Wagner Jahr. 15, 172-174; 1869.

to the fact that Favre and Silbermann obtained 258.5 cal. as the heat of combustion of the molugrams of CS_2 , while the same weight of C and S gave only 24.5 cal., yet at a temperature sufficiently high to decompose the CS_2 no explosion took place. In his *Sur la Force des Matières Explosives* **1**, 196; 1883, he gives the heat of formation of CS_2 as -0.55 cal. for the gaseous and -7.2 for the liquid state, and in **2**, 149; 1883, he states that he has detonated the endothermic gases by means of mercury fulminate.

Under the rather inept title, "The Direction taken by Explosives," Charles E. Munroe combats, in the *Illustrated American* **3**, 286; 1890, the popular notion that "high explosives explode downwards while gunpowder explodes upwards," and illustrates his argument by photographs of results obtained in practice. One of the most important illustrations unfortunately is presented in the reversed position.

We are indebted to the courtesy of Major J. P. Cundill, R. A., for a copy of the "Addenda to Dictionary of Explosives,"* bearing date of 1890, which brings the literature of the subject as treated in his very valuable work up to date.

M. Eissler, whose "Modern High Explosives" is so favorably known in this country, has published a "Handbook of Modern Explosives,"† which is in many particulars a better book, as it covers more ground and contains fresher data. We understand that owing to existing copyright there are some obstacles to the introduction of the work into this country.

Vivian B. Lewes, "Service Chemistry,"‡ prepared by the Professor of Chemistry at the Royal Naval College especially for the instruction of naval and military men, gives a very clear exposition of the subject of explosives as regarded from a chemical standpoint.

Through the courtesy of M. P. F. Chalon we are in receipt of his "Note sur les Poudres sans Fumée,"|| which gives an admirable presentation of this subject up to the date of publication.

* W. & J. Mackay & Co., Chatham, Kent, pph. 17 pp.

† Crosby, Lockwood & Son, London, 1890, 8vo, 318 pp., 105 ill.

‡ W. B. Whittingham & Co., London, 1890, 8vo, 521 pp., 56 ill.

|| Publications du Journal Le Génie Civil, Paris, pph. 15 pp., 1890.

"Smokeless Powder and its Influence on Gun Construction,"* by J. A. Longridge, presents the results of the investigation by a well-known ordnance expert of the data available for smokeless powders by the use of Sarrau's formulas. His conclusions are that smokeless powder has ballistic properties far superior to the old powders; that the erosive action on the guns will probably be less; that its use in existing guns of the new forged steel type will not lead to any considerable increase of ballistic effect *without considerable risk*, owing to the increase of prèssure developed in the front part of the chase, although the actual maximum pressure on the gun may be less; that to utilize the high ballistic powers of the new powders very strong guns will be required, and that such guns will have to be much stronger *in front of the trunnions* than those of the new type forged steel guns: that to arrive at very high ballistic results it is not necessary to have guns of inordinate length, but by the adoption of higher initial, instead of low and more uniform pressures, velocities of 3000 feet per second and upwards are attainable with perfect safety. This points, in his opinion, to the wire system of construction, and he urges that immediate experiments be made to enable new ballistic formulas to be constructed, and determinations made of the tensile strain on the chase caused by the friction of the products of combustion.

B. Westermann announces "Methode zur Zerstörung von Felsen in Flüssenmittels aufgelegter Sprengladungen," by Johann Lauer.

Charles E. Munroe has in press Part II. of his "Index to the Literature of Explosives," in which the periodicals indexed in the first part are brought up to 1890; and in addition Dingler's Polytechnisches Journal, Proc. American Chemical Soc., Nicholson Jour., Edinburgh Jour. Sci., and Popular Science Monthly are indexed from date of first issue up to 1890, making in all 843 volumes which have been reviewed.

* E. & F. N. Spon, London, pph. 49 pp., 1890.

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U. S. NAVAL INSTITUTE, NEWPORT BRANCH.

OCTOBER, 1892.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XXIV.

On account of its value, we reproduce at length, from the J. Soc. Chem. Ind. **II**, 203-212, 1892, Oscar Guttman's paper on "The Dangers in the Manufacture of Explosives." With a few exceptions, the dangers in connection with explosives may be summed up in the terrible word "explosion." Those who have witnessed one are never likely to forget the impression. A sharp report, huge red flames shooting towards the sky, followed by indistinguishable dark masses, then a dull shower of falling pieces, followed by a dead silence. Where a second ago a neat-looking building stood, and busy hands were working, there is now a deep hole in the ground, and all around at great distances lie scattered the fragments of house, machinery, and workers. It is difficult even to identify these last. Their clothes, if not of wool, are burnt away, their features are no longer recognizable, and sometimes a boot, or a limb, or a mark on the body is the only clue. The cause of the explosion can rarely be traced with certainty. Whoever has read the reports of Her Majesty's Inspectors of Explosives will have nearly invariably found more than one possible cause given, but they will at the same time have been astonished to find a power of generalization displayed which has never yet failed to teach some sound moral for the benefit

* As it is proposed to continue these Notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications, or trade circulars. *Address, Columbian University, Washington, D. C.*

of those concerned. Unfortunately such reports are published only in Great Britain, and the few short notices which reach other countries are quite insufficient to give manufacturers adequate information to enable them to provide effectively for the protection of their work-people and their property. A feeling that it is the duty of each one to relate his experiences has led the author to give an outline of the sources of danger involved in the manufacture and use of explosives.

It is generally agreed that an explosion must first be defined as the sudden decomposition of a mechanical or chemical mixture into its components, whereby in a short space of time a great pressure is developed. Such an explosion may be started by different means, and they are by no means the same in each case. Sometimes ignition will start the decomposition, sometimes a shock, friction, an electric spark, vibration, sudden heating, etc.; but as a rule it is necessary, as Sir Frederick Abel pointed out first, that a certain amount of vibration, and vibration of a distinct nature, be generated as a result of either of the above causes, in order to produce explosion.

The explosion is quicker, the larger the number of vibrations in unit time. The stronger the effect, the higher the heat produced and the larger the quantity of gases developed, as their expansion increases in proportion to their temperature. An explosion has the maximum effect when the vibrations, the heat, and the quantity of gas reach their maximum at the same time.

Here may be mentioned some of the more conspicuous examples of explosions. Chloride of nitrogen explodes when thrown into boiling water. If a minute piece of paper, smeared with iodide of nitrogen, the temperature of explosion of which is 212° F., be allowed to fall from a height of about 3 feet, it will explode on touching the ground. If such a piece of paper is put on a base-viol and the E chord is struck, it is not influenced, but if the G chord be struck, which gives more than 60 vibrations in the second, it explodes. If a gunpowder mixture be ignited in a tamped bore-hole it burns away by layers until the pressure of gas and heat cause explosion. If dynamite be ignited in this way it will simply burn without detonation. If laid on an anvil and struck sharply at an angle ("glancing blow"), all explosives in practical use will detonate. Dynamite explodes between steel and steel when 5.63 foot-pounds of work are done upon it (0.78 kilogramme-metres), gunpowder at 56 foot-pounds (7.57 kilogramme-metres); but whereas the explosion travels through the

whole of the gunpowder, dynamite, as a rule, only detonates in the part struck by the blow. If a dynamite cartridge be exploded on the top of a gun-cotton charge the latter will only burn away, but if the places are reversed the gun-cotton is sure to detonate the dynamite. Each explosive has a certain temperature beyond which it cannot be heated suddenly without detonation. This temperature is, for example, 212° F. for iodide of nitrogen, from 356° to 363° for nitro-compounds, and 518° to 608° for gunpowder.

It is therefore obvious that an explosion is not solely due to the explosive being heated to a certain temperature. In fact, the shock or friction may be quite insufficient to raise the temperature to any appreciable extent, even if the shock be concentrated on a single point, as in the case of a "glancing blow."

On the other hand, anything which is likely to produce vibrations of a sufficient amplitude and frequency in the explosive should be carefully guarded against. Thus, for instance, it is well known that a tuning-fork will give a greater number of vibrations if struck against an object of steel than against brass, stone or wood; and the same applies to any shock against an explosive lying between different bodies. Steel against steel is the most dangerous, wood against wood the most harmless. Yet it has been proved by Dr. Dupré that a glancing blow with a broomstick against a wooden floor will cause the explosion of most explosives. Of course it depends greatly in what condition the explosive itself is. A blow given to a full cartridge of blasting gelatin may be quite harmless; but if sufficient force be used to flatten the cartridge and expose the last thin layer to a sufficient amount of shock, then an explosion of the whole cartridge may follow. There is also a great difference between the explosive being warm or cold. When warm, explosives are as a rule more sensitive, both to decomposition and to shock or friction.

The causes of explosions may be placed under two headings, mechanical and chemical. The mechanical causes are mainly due to shock, friction, or ignition of some sort. The chemical causes vary with the nature of the explosive. Mechanical mixtures, such as gunpowder, roburite, etc., are, under ordinary circumstances, exempt from dangerous chemical changes; but chemical compounds have always a certain amount of instability, which can only be avoided by careful manufacture. Of course there are also mechanical mixtures which are liable to decomposition, and I need only mention the chlorate mixtures, which, especially in the case of fireworks, have led to many accidents.

In the following account each explosive will be dealt with separately, and the dangers attached to it at each stage of its manufacture pointed out. Of course only those explosives which are actually manufactured and in use will be spoken of, it being left to you to draw your own conclusions, by the similarity of cases, when other explosives come under your notice.

Gunpowder.—First by seniority and by the number of factories making it come gunpowder and its imitations. In this case, as in that of every other explosive, a very important condition is that the materials employed should be of the greatest possible purity, both chemically and mechanically.

In the nitrate (saltpetre, sodium nitrate, etc.), chlorine is the principal impurity. Although in the case of true gunpowder no saltpetre is now used which contains more than one ten-thousandth part of chlorine, yet with gunpowder imitations, especially where sodium nitrate is used, this is not always the case. An assistant of mine once made some powder mixture, extracted the nitrate, which contained a large amount of chlorine, from it, evaporated the solution in a porcelain dish to dryness and complete fusion. He then allowed it to cool, and after some time began to move the cake with a glass rod, when suddenly the whole flashed up. In this case it is evident that some nitrogen chloride had been formed, the liability of which to explosion by the slightest vibration is so well known.

Care has also to be taken that no saltpetre or powder comes in contact with a soldered joint. Weber found in a particular case that nitrate of tin was formed, of which there is an explosive variety; this has caused frequent accidents.

The charcoal presents no other danger than that of spontaneous combustion. It is a good practice to have the charcoal first ground in separate machines. Spontaneous combustion is due to the capacity charcoal has of absorbing and condensing the air, producing thereby heat. This may sometimes take place suddenly, as, for instance, when a piece of charcoal is broken, and the interior, which has preserved its absorbing power, is brought into contact with moist air.

The sulphur is now generally ground before mixing it with the other ingredients. Although by quick grinding a large amount of heat may be produced, this is scarcely ever sufficient to fire the sulphur. But sulphur mills very often take fire, and this is chiefly due to the well-known electrical qualities of sulphur, which are made evident by the friction and heat in grinding. A friend of the author

connected his sulphur mills with the earth by means of copper wires so as to carry away the electric charge as it was produced ; since this time he has never had a sulphur mill fire.

If a ventilator is used to carry away the sulphur dust, its exhaust-pipe should go into a collecting chamber, as sulphur dust is dangerous.

In this country stamp mills are no longer used for the incorporation of gunpowder, but elsewhere they still exist. They have generally wooden beds and brass stamps, and but for the presence of grit, or some broken metal parts, they are safe enough, provided the powder is frequently "liquored." Still, most of the accidents occur with them, as these two conditions of safety are often accidentally absent, and the great amount of dust, thrown in the air by the violent blows of the stamps, takes fire easily by a spark, or by the friction of a stamp-pole.

Mixing drums were formerly largely used, and seem to be coming into use again in this country, for certain kinds of powders. As they are made of "sole" leather or wood with brass or wood balls revolving in them, there should be no other danger in them than comes from overheating due to the quick movement. There is still another source of danger which will be dealt with presently.

The machines chiefly used for the intimate mixture of the gunpowder ingredients are the "incorporating mills," having generally pans and runners of cast-iron. Sometimes the beds are made of wooden blocks on edge. Incorporating mills are known to explode from time to time, and formerly the well-worn excuse of a match or a nail having got into the mill used to be a readily accepted explanation of the accident. Such an occurrence of course is possible, but must be very rare indeed. The chief cause is faulty construction of the mills. The runners weigh from four to five tons, and if the cake in the course of milling becomes dry and hard, the runner may lift in passing over a thicker piece and then fall down on to a thin one. Good incorporating mills are now made in such a way that the runners always remain one-sixteenth inch off the bed, so that the iron can never come in contact with iron. Another cause, which applies to mixing drums and nearly all other powder machinery, is electricity accumulated by the friction against the sulphur. Some years ago the author devised the "earthing" of incorporating mills, and he believes that the number of accidents has considerably diminished where his suggestion has been adopted. It is known that many of

the explosions in incorporating mills happen where they are suddenly stopped or started after a stoppage, whereby a great amount of vibration is of necessity set up in a single moment. Many accidents happen also in removing the cake from the bed, or when repairs are being made. It is essential and rightfully enforced by Her Majesty's Inspectors that the cake should only be taken away when damp, and that no repair should be done without having previously thoroughly washed and cleaned the whole building. The use of brass tools in such a case is only a diminution of the risk, and is not by any means a safeguard against accident, and even wooden implements should only be used after the charge is well moistened. To prevent communication between one mill and another, which very often are driven in pairs from one water-wheel or line of shafting, the drenching apparatus has proved to be very effective. Briefly, this is a water-tank placed on the top of a mill, and held in equilibrium by a "shutter," a flat lever board, which, when raised in the least degree, upsets the tank. All the shutters are connected by a shaft, so that when an explosion in one mill takes place, all the other charges are immediately drowned.

When an incorporating mill explodes, the building only is, as a rule, damaged, and that not always much. A friend of the author's has adopted the excellent system of constructing the roof of the building with a very light framing, and securing the whole roof by two loose wooden pins only. If an explosion occurs the roof is simply lifted, giving enough opening to the gases to escape before sufficient pressure to materially damage the building can be set up.

The mill cake is next powdered in a "breaking-down machine," which is essentially a roller mill with one pair of grooved and one pair of plain rollers. This machine requires no more attention than any other powder machinery, except that it should be so made that the pressures on the rollers cannot exceed a certain limit. This is generally done.

Next comes the pressing, which is now generally done by hydraulic machines, roller presses being very rarely used. Formerly this pressing was done by placing in a square wooden box with hinged sides a layer of powder meal and a brass plate alternately, and then pressing a block of hard wood into the box. This caused the powder to adhere so strongly to the sides of the box that it required a good deal of force to open it, and sometimes occasioned accidents. Nowadays the damp powder meal is, as a rule, laid on an ebonite

plate, another placed on the top of it, and so on, layers of powder and ebonite occurring alternately until the required height is reached. This way of pressing is comparatively safe, provided great care is taken to keep the presses clean, and the hydraulic ram is not allowed to fall down too quickly. But there is again the danger of electricity, which in this case especially must not be underrated. The charge of a cake press with ebonite plates can practically be considered as an electric pile, and a large amount of friction or electric influence from outside may cause a sufficient electric charge to give off sparks. Several cases have been known, and the following instance occurred at a large Continental factory. The workman, having just finished charging, opened the valve for the hydraulic pressure, when he became aware of an approaching thunderstorm. According to his instructions he left the building and returned after the thunderstorm had passed away, but when he began to discharge the press it exploded. The man died, but stated before his death that in undoing the cakes a spark four inches in length came on his finger.

It is therefore advisable to take great precautions in using ebonite. It is a very convenient material, being very tough, of smooth surface, hard and not subject to much wear and yet sufficiently elastic; it is, therefore, largely used for plates in cake presses, for the lining of hoppers in granulating and sifting machines, etc., but care must be taken that no electricity can accumulate even under unfavorable circumstances.

The reduction of the powder cake into grains is done by a machine similar to that used for breaking down the mill cake; the grains formed are continuously classified as they fall from the rollers by sieves placed underneath. There is a large amount of dust produced in this operation, and the author has not yet seen a single graining machine where the escape of dust into the room has been perfectly avoided, but he has seen many houses where the air looked worse than a London fog, and where with open doors you could see the cloud of powder dust coming out for more than three yards. As a matter of course, there is shafting in the house, the graining machines themselves contain a number of cog-wheels, bearings, etc., and sometimes the shafting itself is driven by a cog-wheel from another line of shafting. These cause a good deal of noise, which, together with the darkness in the room, produces a very uncomfortable feeling.

In many factories the graining is still done by the Lefebvre system, which consists of one or more sieves oscillating either longitudinally or in a circle, in which a weighted boxwood disk, hewn like a millstone, is moved to and fro, thereby breaking the cake. This way of graining produces, of course, still more dust.

In some places a ventilator may be found which draws out the powder dust through an opening in the building, and deposits it on sheets of cloth, but it is never efficient enough to clear the atmosphere of the room. It is the author's belief that a suitable casing round the graining machine, and a hood on the top in connection with a good exhaust, leading in a depositing chamber, would answer the purpose much better. No cog-wheels should be allowed on the shafting inside the building. They do not always gear perfectly, and wear out in time, which causes dangerous knocks, and it would perhaps be advisable to put the shafting altogether outside the house, unless it runs at a low speed. The bearings of the graining machine should be provided with constant lubricators, such as Stauffer's solid grease cups, which prevent the inconvenience of the oil dripping about, and keep the bearings constantly greased.

During the glazing, rounding, and sieving, the powder is subjected to a constant friction of its particles against each other; and during the glazing especially, where there is still a large amount of moisture, a good deal of heat is developed. The plugs in the glazing barrels must be opened at regular intervals to allow the escape of steam formed, and care should be taken with all these revolving machines to carry away any electric charge that has accumulated, which is easily done.

The drying of the powder is no longer done in the open air, however convenient this may have been. There was always the risk of grit flying into the powder, and of concentration of the sun's rays, if exposed to it. Artificial heat is now generally resorted to, and in very few cases only are the fumes of a stove carried in pipes to the drying house. Steam, hot or warm water, are nearly always adopted now. The introduction of steam or hot water pipes into the building itself is objectionable, as a certain amount of dust, which is always produced in charging and emptying the trays, accumulates on the hot pipes. Warm water pipes increase the time of drying a little, but are not open to this objection. The best way is certainly to have a steam or hot water stove outside the building, and to drive, by means of a fan, a current of air over the stove into the drying cham-

ber. This allows an even temperature to be kept, and removes all danger, provided that the air inlet be so arranged that the current of hot air cannot pass directly over a layer of powder.

Sometimes the press cake is cut in large cubes for the so-called pebble or cube powder. No special allusion may be made to these machines, whatever may be their construction, as the exclusion of hard blows, the attention to knives, bearings, etc., is the same as with all other powder machinery.

The process which requires the most attention, and which is not always in expert hands, is that of compressing the powder into prisms, cylinders, pellets, etc. There are two classes of presses in use, lever and hydraulic presses. With a lever press generally the powder is charged into a mold, closed at the bottom by a piston, and another piston is brought down on the top by a lever actuated by an eccentric. Of course there is a great variety of such presses. Some have a "block" with many holes, into the bottom of which comes a disk, then the powder charge, then a piston, and the whole goes under a press. In some presses the mold revolves on a table, and its holes are alternately opposite a plain part and a perforated part of the table, and, at the same time, subject to a piston compressing the charge, and, on another part, to a longer piston forcing the compressed cartridge through the hole in the table, whence it falls out in a receptacle. Sometimes a hopper slides over the mold, fills it, glides away, and the charge is forced out. Sometimes the mold is fixed, sometimes it is balanced during the compression, whilst a piston enters the mold from the top and from the bottom.

These latter presses are, perhaps, the best in the way of lever presses, provided the mold be guided vertically, and one of the two pistons has a safety arrangement, to prevent excess of pressure. Lever presses, where more than one cartridge is pressed at a time, are objectionable, as they seldom have a safety arrangement, and to make such a one effective would cost as much as a suitable hydraulic press.

It is well known to everybody who has had to do with the compression of pulverulent substances, that it is most difficult to have a number of molds filled with exactly the same quantity in each. Even little hoppers, which open at a certain weight, will fail to give more than a rough equality. Also the state of the atmosphere and the shape and diameter of the mold make a difference, as does also the size of the grains in the case of gunpowder.

Although gunpowder can bear a great pressure without injury, yet it is not advisable to do much in this direction, as it is very easy to get local overheating by the presence of a foreign particle or a hard grain. Also the more powder is compressed, the more it will adhere to the mold, and in pushing out the cartridge a greater pressure will be required. It is the friction thus caused which produces the greatest heat, and where the most danger exists. When, therefore, a number of molds are not equally charged, and they are all compressed by pistons fixed on a common head, the cartridge which contains most of the powder may, at a certain stage, receive all the pressure intended for the lot, and will, in any case, get more than its share. Hence the necessity of an arrangement to prevent an excess of pressure. This can be done by weighted levers on the bottom pistons, or, much better and simpler still, by keeping each mold independent and movable.

The same applies to hydraulic presses. Most of them have one ram only, so that the cartridge, which may vary from $1\frac{1}{2}$ to 3 inches in height, is far more compressed on the bottom than on the top. Those with one ram on top and bottom make a better compression, and want less pressure on either side, but they are costly and cumbersome. In neither of them, as a rule, is any arrangement to prevent an excess of pressure provided, and the best means of doing this is the movable mold.

Presses for prismatic powder, where needles of phosphor-bronze enter the molds, require careful inspection, as the slightest bend of a needle can cause breakage.

Another method of powder manufacture may be briefly mentioned, which was long ago known to the Tartars, and some nine years ago practised in this country. This method is to dissolve the saltpetre in hot water, add the other ingredients, and boil down the whole with constant stirring during the evaporation. The English system of inspection would have soon put a stop to the way in which this was done for some time on the Continent, where this process was carried out in a kind of washing copper with a coal fire underneath, and where the contents of the copper sometimes went off through part of the powder being caked at the bottom and excessively heated.

The manufacture of cocoa-powder does not differ from that of ordinary gunpowder except in the preparation of the charcoal, which is no more dangerous than the work of a rag-boiler.

In connection with gunpowder may be mentioned also the manu-

facture of safety fuses. This presents no particular danger, except that in spinning the first layers of the fuse, where a fine stream of powder falls in as the fuse is formed, the excess of powder falls on the floor, covering a large area, requiring precautions to be taken against friction or the fall of the weight which keeps the fuse stretched.

Nitro-compounds.—The next group to be dealt with are the so-called nitro-compound or chemical explosives. These are produced on a very large scale, and gain daily in importance; but their manufacture involves generally a great amount of machinery and apparatus, and the knowledge of all the accompanying circumstances is still far from being perfect, besides being sometimes of a very complicated chemical character.

Nitro-compounds are liable to explode at a lower temperature, are more sensitive to concussion and friction than gunpowder, and in addition, as products of chemical action, are liable, under unfavorable circumstances, to undergo chemical changes which may render them unstable.

A nitro-compound is generally formed by the action of nitric acid on a hydrocarbon, sulphuric acid being added in order to take up the water formed during the process and to keep the nitric acid as far as possible at its original strength, so as to avoid the formation of lower nitro-compounds, which would either reduce the force of the explosive, or even render it unstable.

Comparatively the least dangerous to manufacture are gun-cotton and collodion cotton. With the exception of the nitration and the compression into cartridges, the whole process is worked with a large excess of water, and although it is quite conceivable that a particle of gun-cotton surrounded by water may explode when struck by a heavy weight, yet such a case is hardly likely ever to occur.

The cotton has to be very carefully purified from resinous matter and soluble substances, as they would form unstable by-products if allowed to remain. This is usually effected by boiling the cotton in a solution of soda. The nitration is done in England by dipping the cotton into the mixture of nitric and sulphuric acids, which are contained in a cast-iron vessel, squeezing it roughly out on a grid, and then letting the nitration complete in earthenware pots, which stand in running water. On the Continent they employ nitrating machines, consisting of a cast-iron vessel with a lid screwed on, having a false bottom which can be moved by means of a screw passing through

the lid. The cotton remains in the machine during two hours, and then the false bottom is lifted towards the lid, thus squeezing the cotton out. In another factory suction is applied underneath the false bottom to drain the cotton.

The nitrated cotton is further deprived of the bulk of its acid by treatment in a centrifugal machine, whence it is passed as quickly as possible into a washing machine.

Care has to be taken that the acid cotton remains constantly under the acid or the water, or at least well covered, else, as it absorbs moisture rapidly, it decomposes, and once a decomposition is started it is almost impossible to stop it. This decomposition is attended by large volumes of red fumes, and sufficient means of ventilation and escape for such have to be provided from the outset in case they are formed. The warmer the mixture, and the less liquid acid it contains, of course the more liable it is to decomposition, hence it is on warm and moist days centrifugal machines are most liable to fire; this seldom happens in the winter, unless some water, oil, or other foreign material falls into it.

Once it is immersed in the washing machine, whose water has to be constantly changed, the gun-cotton is no longer subject to sudden decompositions during the subsequent processes of manufacture, but the acid still remaining in it has to be eliminated with the greatest care, or else a gradual decomposition will take place. I will not detail this manufacture, as it is well known; suffice it to say that gun-cotton which stands the English Government's heat tests is quite safe under all ordinary circumstances.

The compression of gun-cotton into cartridges requires far more care than that of gunpowder, as this is done in a warm state, and gun-cotton, even when cold, is more sensitive than gunpowder. When coming out of the centrifugal machines the gun-cotton should always pass through a sieve, in order to detect nails or matches which may by chance have got into it. What has been said as to gunpowder presses applies still more to those for gun-cotton, although the latter are always hydraulic presses. Generally the pistons fit the mold perfectly, that is to say, they make aspiration like the piston of a pump. But there is no metal as yet known which for any length of time will stand the constant friction of compression, and after some time the mold will be wider in that part where the greatest compression takes place. The best metal for this purpose has proved to be a special steel made by Krupp, but this also is only

relatively better; for pistons I prefer hard cast-iron. If the position of the molds and the pistons is not exactly the same in all cases, what the Germans call "Ecken" (English, "binding") will take place, viz., the mold will stand obliquely to the piston, and a dangerous friction will result.

For certain purposes, such as torpedoes, engineers' cartridges, etc., the gun-cotton has to be turned in a lathe, or drilled or planed. This should always be done under a constant stream of water, to keep the tool cool, as well as the gun-cotton in contact with it.

Of course, it is necessary to protect the man working the hydraulic valves during compression. At Waltham Abbey they have a curtain made of ships' hawsers which is at the same time elastic and resistant. The author has found from experience that a partition wall 12 inches thick, made of 2-inch planks, and filled with ground cinders, gives very effective protection. There are scarcely ever more than 5 lb. of gun-cotton under pressure at the same time, and in the case of an explosion the parts projected embed themselves in the timbers. The roof or one side of the building should be made of glass, so as to give the explosion a direction, and as a matter of fact it will not injure the walls of the building, even if they are only one brick thick.

The drying of gun-cotton is no less attended with risks, if it is done by improperly constructed arrangements. It is generally accepted that the drying should not take place at a higher temperature than 104° F. To secure this an electric alarm thermometer should be provided. If a current of hot air passes over a layer of gun-cotton, the cotton becomes electrified, and most, if not all, the fires in gun-cotton drying houses are due, in the author's opinion, to a neglect to carry away this electricity.

I am indebted to Mr. Walter F. Reid, F. C. S., for much information in this respect. He was the first, so far as the author knows, to make metal frames, carriers, and sieves, upon which is secured the cloth holding the gun-cotton, and to earth them.

In drying-houses there is a large amount of gun-cotton dust produced, which deposits on walls, floors—in fact everywhere. This dust, being warm, is very sensitive to friction; in fact, Colonel Cundill once told me that even the hard friction with a felt shoe had been known to fire it. The workers in these rooms should therefore always wear felt shoes or go barefooted, avoid all unnecessary friction, and frequently wash the floors and walls. The floor should be covered either with india-rubber or linoleum.

On no account should an exposed metal pipe for the conveyance of heat be allowed in the drying room. Although the heat may not exceed 104° , and the radiation of the pipe may be sufficient, yet there might be a more sheltered place, such as a bend, a corner near a wall, etc., where the quantity of heat is accumulated, and a far higher temperature reached than that of the air entering, and it is just such places that will be filled with cotton dust, which itself will serve as an accumulator of heat. An accidental blow on the metal pipe may also happen, so that it is best to exclude them altogether from the room.

The above remarks about gun-cotton apply to mixtures of nitrate and gun-cotton, such as tonite, potenite, etc.

The manufacture of nitroglycerin and dynamite is by outsiders generally considered as an extremely dangerous one, and it certainly is in the hands of untrained and inexperienced people; but if conducted by experts it is far less risky than the manufacture of gun-powder. Still, as it is essentially a chemical operation, its safety will always depend upon the amount of care bestowed on it by the work-people; it requires a great deal of supervision to be always on the watch for neglect of duty.

The sources of danger rising from the raw materials will first be considered. The nitric acid used should be reasonably free from peroxide. Opinions differ as to what is a reasonable amount, and no doubt the heat developed during the process of nitration is increased by the presence of this, a large amount of hyponitric acid; and, if sufficient care be not taken, may cause decomposition and explosion. Some say it should not contain more than 1 per cent.; but some of the most perfectly conducted factories use it with even more than 4 per cent. The author's experience has been that nitric peroxide undoubtedly produces more heat by its great oxidizing power, but as the temperature of the mixture is always kept under about 77° F., it means that the nitration will last longer, because the workman must allow less glycerin to run in, and consequently he is expected to be still more attentive. Hyponitric acid also reduces the yield of nitroglycerin considerably. As a rule, those factories which buy their nitric acid insist upon having as little hyponitric acid as possible, sometimes below half a per cent., and those which make their own acid are not particular about 1 per cent. more or less. If the process of nitric acid making is conducted in such a way that a minimum of hyponitric acid be present, it will be difficult to have more than 93 per cent. pure monohydrate, and a large quantity of weak acid will

result. If highly concentrated acid only is made, containing 95 to 96 per cent. pure monohydrate, then more heat has to be applied, which will always decompose some nitric acid into hyponitric acid. Of course, a high percentage of monohydrate and no weak acid are most to be desired, because the first gives infinitely better results, whilst the latter is of little value, and if, therefore, the hyponitric acid should be eliminated, then a costly and tedious process of bleaching is necessary. This is the reason why a dynamite factory which makes its own nitric acid has never been known to have less than 2 per cent. of hyponitric acid as an average, but some even as much as 7 per cent. A new process which the author has recently invented gives invariably less than 1 per cent. of hyponitric acid with from 95 to 96 per cent. pure monohydrate, and this is now being rapidly introduced into many factories. This process can even be worked in such a way that the acid will not contain more than one-tenth of a per cent. of hyponitric acid, and acid with even as much as 99.40 per cent. pure monohydrate has been made by this process. This is the strongest acid ever manufactured on a large scale, but there is a great amount of the possible yield lost. It may therefore be said that unless the nitric acid is after its manufacture submitted to a long and expensive bleaching, the best which can be made on a commercial scale will always contain about 1 per cent. of hyponitric acid. As it is scarcely to be expected that everybody can have the very best acid, the limit of hyponitric acid may be set at 2 per cent., which does not increase materially the danger of too much heat being developed. Beyond this limit the heat of the mixture may rapidly increase, and the workman has to be constantly on the alert to shut off the inflow of glycerin, or to apply more vigorous cooling and stirring. As it is desirable that every process should depend as little as possible on the attention of the workman for avoiding accidents, an excess of hyponitric acid should not be allowed.

Sulphuric acid and glycerin are nowadays made very pure. Arsenic may be in both, especially in the sulphuric acid, but it should never be allowed to exceed one-tenth per cent. on account of the well-known strong oxidizing action of arsenious acid.

Glycerin is a very intricate substance, so far as its use for making nitroglycerin is concerned. Of course, a large amount of organic matter, such as cellular substances from the tissue or fatty acids, are both objectionable, as they form unstable compounds during nitration. The presence of chlorine has also to be avoided, because it will

ultimately form hyponitric acid. But even if the glycerin is nearly perfectly pure, and contains nothing whatever but about 0.15 per cent. of total residue, organic and inorganic, it will sometimes happen that the nitroglycerin made is full of a bulky, flocculent matter, which prevents its separation from the acids for a very long time. This only happens with glycerin of a special manufacture, and up to now even so high an authority as Mr. Otto Hehner has been unable to find out to what component or impurity this is due.

The operations of nitrating and separating the nitroglycerin do not require more attention than that the temperature should not even at the finish exceed 86° . I do not refer by this to the Boutmy-Faucher process, which in itself had a special source of danger, inasmuch as in it the sulphuric acid was first allowed to act upon the glycerin, which caused the organic impurities to become charred and to form minutely suspended carbon particles. This prevented the nitric acid, at its highest concentration, penetrating every particle of glycerin, and sometimes prolonged the separation for days. It will be explained later on why this must have been dangerous, or is still so, as the process is still said to be used on a small scale at the French Government factory at Vonges.

It is in the apparatus used for nitration and separation that the chief danger lies, on account of their construction. The nitrating apparatus is now generally a large lead tank, with a number of cooling worms, through which cold water runs. The tanks are closed at the top, with suitable openings for the admission of glycerin and compressed air, for the escape of the fumes, and for the constant control of the temperature, also for discharging the tank either into the separating apparatus or into a drowning tank. All these arrangements of course complicate the nitrating apparatus, and require constant attention. A detailed description of the different apparatuses in use cannot be given in this paper, as it would be sufficient for a paper by itself, but some of the chief sources of danger, however, must be pointed out. First is the lead itself usually used in the construction. The combined action of nitric, nitrous and sulphuric acid on the lead is very great; but still greater is that of the fumes, when mixed with the outside air, because diluted acid attacks metals more than strong acid. The lead should be perfectly pure; some even prefer remelted old lead, as it becomes harder by remelting. If the slightest amount of zinc is present the lead is very soon perfectly honeycombed. The fumes should be drawn off

through a pipe with a good draught in it, so that the outside air cannot enter the vessel. The compressed air used for stirring and cooling should come from a storage vessel, where it can deposit all its moisture, and the pipes leading to the apparatus should ascend as much as possible, and have a drain-tap attached. All joints should be made quite tight, and the construction of the cooling worms must be well understood, as they will expand and contract, and can easily leak. It must be understood that the slightest leak of water pipe may start a very serious decomposition, and it is therefore a good plan to test the whole apparatus every morning before starting work.

The manner of introducing the glycerin is another matter for consideration. In some apparatuses where a screw paddle assists the stirring, the glycerin runs on a disk attached to it, and is therefore scattered by centrifugal force in minute drops. Sometimes a perforated pipe supplies the glycerin, and very often an injector. Those injectors which are placed near the bottom of the vessel are soon eaten away, and sometimes cause a sudden inrush of glycerin, which is of course to be avoided. Injectors or pressure vessels which blow the glycerin through a pipe are perhaps the best.

The temperature in the apparatus must be efficiently controlled; it is not sufficient to know the temperature of one part of the vessel only, since decomposition generally starts locally and then spreads over the whole mass.

The taps for discharging to the separators and to the safety tanks want very careful fixing, and it is commonly said that it is a knowledge of itself to make all the different kinds of mastic or cements that are required in a dynamite factory. Of course the taps must not be placed so that water can get into them. At the same time much depends upon what pressure there is on the tap, and one of the objections to those huge American apparatuses is that they have a column of acid 10 or more feet high resting on the taps, and exerting about 8 lbs. pressure per square inch. It is so easy to get a tap or a plug knocked out, apart from the pressure on the tank and the enormous weight of the cooling worms.

The apparatus should of course be made so as to empty itself to the last drop, and the safety tap should be sufficiently large to empty the vessel in a few minutes. Exactly the same remarks apply to the first separators and the bottles used in the secondary separation.

It might be appropriate to mention here that a decomposition in a properly constructed apparatus is a very rare occurrence indeed,

and due only to leakage, bad glycerin, or inattention on the part of workmen. Even if a decomposition should be seen starting, there is no need to drown a charge at once, or to lose one's head and run away. A decomposition, as has been mentioned, begins at one point and spreads gradually through the whole mass. A slight decomposition will develop a huge volume of dark red fumes, and is certainly alarming to the novice, but it will take sometimes ten or more minutes before it can develop into an explosion. The author has seen decomposing charges entirely saved by the coolness of the workmen, who freely used all the available means for cooling and stirring. In one instance, the acid underneath the nitroglycerin in a separator decomposed, and the man in charge, who was a new hand, in his confusion opened the nitroglycerin tap instead of the safety tap, and although the whole of the nitroglycerin had time to run into a water tank, it was more than a quarter of an hour before one could think of entering the building to drown the decomposing acid.

In the process of separating the nitroglycerin from the acids there is the danger of a prolonged contact of the two liquids, which has been fully investigated by the Home Office in reference to the Pembrey accident. Nitroglycerin dissolves in sulphuric acid, and just at the line of contact between the two liquids many of those lower nitro-compounds collect which have been formed from the impurities in the glycerin. Others collect on the top of the nitroglycerin, where they are exposed to the action of the air. Pure nitroglycerin can remain a very long time in contact with pure nitric and sulphuric acid without alteration ; but in a process where everything is impure, the lower nitro-compounds are soluble and unstable, and therefore the separation should be finished as quickly as possible. I have referred already to the glycerin retarding the separation, but there are also mechanical impurities in the other reagents which have even worse effect. If the sulphuric acid contain much lead, if the mixed acids have been in the storage tanks too long, and some lead or iron is dissolved in them, this will be suspended in minute, but bulky, quantities in the mixture of nitroglycerin and acids which leaves the nitrating apparatus. Still more marked is this effect in the case of any carbonaceous matter introduced, such as straw from the carboys, gross organic impurities of the glycerin, etc. This is the case with the Boutmy-Faucher process, where, by dissolving the glycerin in sulphuric acid, the impurities in the former are charred and delay the separation in an extraordinary way. The

worst case known to the author was one when a second-hand air vessel was bought for the storage of sulphuric acid and a thick layer of rust prevented it being seen that the vessel had formerly been coated inside with tar. The sulphuric acid became quite black from the tar, and after two days' separation only half of the nitroglycerin could be recovered.

It must be understood that the difference of specific gravity between the nitroglycerin and the refuse acids is only 0.100, the former having a gravity of exactly 1.600 and the latter about 1.700, and although the greater fluidity of the acids facilitates to a great extent the separation, yet such bulky impurities remain for a long time suspended and form contact between the more sticky nitroglycerin and the acids, thus obstructing separation.

The secondary separator receives the spent acids, which generally contain minute globules of nitroglycerin in suspension, and it is essential that they should have time to separate. This secondary separation is the weakest spot in a dynamite factory. The fact that small quantities of highly acid nitroglycerin are floating on the top of strong acid, and, even with the best ventilating tubes, are exposed to the air, may account for some decompositions, but the author believes that a careful investigation of all the facts would nearly in every case point to another cause for an accident, that cause either a leak of a water-pipe or the intrusion of some organic matter.

Some of the experiments which the author has carried out with waste acids have shown that if large quantities of glycerin are poured into waste acid (which has nearly invariably the composition of about 10 nitric monohydrate, 70 sulphuric monohydrate, and 20 water), a turbulent decomposition takes place in a very short time. If we take the process of nitration to consist of an interchange between the NO_2 group of the nitric acid and the hydrogen molecules of the glycerin until complete exhaustion of the former, then every particle of glycerin entering in excess will not be nitrated, but dissolved in the sulphuric acid, as after the formation of the bulk of nitroglycerin the nitric acid left occupies about one-fourteenth of the whole mixture, and in spite of violent stirring it is difficult to cause the little nitric acid remaining to come in contact with the glycerin particles. Besides, this nitric acid, as it is seen from the composition of the refuse acids, is in a very diluted state, and if it could easily come in contact with the glycerin, it would only form mono- and dinitroglycerin, which are soluble. Thus it will be seen

that an excess of glycerin forms a very dangerous mixture, and on two occasions at least the cause of decompositions could be distinctly traced by the author to such an excess.

It must be pointed out that a small excess of glycerin may happen with any operation, as it is impossible to calculate exactly the quantity required, and a slight variation in the strength of the nitric acid will at once alter the quantity of glycerin which can be converted into trinitroglycerin.

There is another reason why very strong acid with a rather higher percentage of nitrous acid is preferable to the reverse, as the workman can guard against overheating, but he has no means of ascertaining the total nitrating capacity of the nitric acid. But a small excess of glycerin, although just affording the amount of danger connected with the work, is still not a distinct danger, so long as proper attention is paid. It is only a large excess which can produce a sudden decomposition, and it would be impossible to stop this. This excess of glycerin need not necessarily be the consequence of an error in weighing, it can also be brought about by using too weak nitric or sulphuric acid, or by a mistake in weighing the acids for mixing. The only remedy in this case is to watch the yield of nitroglycerin. If it falls below a certain limit, then part of the glycerin must have escaped nitration, and the only plan to adopt is to at once drown the waste acids, as containing too much glycerin. With good yields of nitroglycerin and proper attention the secondary separation never gives any trouble.

As the waste acids are in most cases treated in a denitrating apparatus to recover the two component acids separately, care must be taken that every particle of nitroglycerin is removed in the storage tanks before working them up. Small drops may come up after days, and an explosion of a denitration plant in Italy was due to neglect in this direction. The storage tanks must also be protected against the weather, and have a safety tank attached, as their contents will sometimes decompose, especially in hot climates.

In the operation of washing and filtering the nitroglycerin, warm water should be used with caution, as nitroglycerin begins to evaporate at 104° , and the inhalation of nitroglycerin vapors in large quantities is injurious.

The other operations do not require more attention than with other explosives, except the formation of cartridges by lever presses, where the material falls through a funnel into a tube, and a piston on

a lever forces the dynamite out in the form of a cylindrical mass. There are two kinds of presses, one where the parchment paper is wrapped around the tube and the whole cartridge is made in one pressing, and others where the dynamite is pressed out by consecutive strokes with the lever, so that a continuous string comes out of the tube. This is broken off when it reaches the required length, and then wrapped round with parchment paper. This kind of intermittent pressing is no doubt the best, and the single stroke presses are rightly objected to by the German industrial inspectors. It is patent that in order to press out a cylinder of soft material of about four inches in length there is perhaps twenty times more force wanted than for a piece of an inch, and any metal or grit particle, or even a hard lump of kieselguhr, may produce enough friction on the tube to cause an explosion. By far the majority of the explosions in cartridge huts happened with single stroke presses. Of course, cartridge presses must be so constructed and secured as to prevent any hard blow or friction.

The manufacture of blasting gelatin, gelatin dynamite, and gelignite calls for very few remarks. As the process is carried out with the aid of artificial heating, care must be taken to avoid excessive heating, since the collodion-cotton may begin to decompose and the nitroglycerin to evaporate. The machines for mixing, if such are used, and for making cartridges must be so constructed as to avoid undue friction, and to allow of ready inspection and cleaning.

The danger of freezing has still to be dealt with. It is well known that nitroglycerin freezes at about 46° F. Dynamite and blasting gelatin will freeze at slightly lower temperatures. Numerous experiments have shown that frozen nitroglycerin and dynamite are highly insensible against a shock, and that even a bullet fired from a military rifle at 50 paces has failed to explode it, whereas soft dynamite explodes readily at 300 and more paces. Yet somehow frozen nitroglycerin does sometimes explode. To the author's own knowledge, the removing of some frozen nitroglycerin from the ground by means of a pickaxe, the sudden turning of an earthenware tap, around whose plug some nitroglycerin froze, the cleaning of vessels containing frozen refuse, and even the forcible breaking of a frozen dynamite cartridge, have resulted in explosions, and it is probable that similar instances are known to others. The author believes that the explosion of frozen nitroglycerin is due to a sudden alteration in the molecular arrangement of the frozen nitroglycerin—such as Professor

Tyndall stated in the case of ice—and the consequent production of vibrations sufficiently high to cause a detonation. This is certainly a striking illustration of the fact that explosion is not merely a result of heat.

Blasting gelatin and gelatin dynamites, on the other hand, are extremely sensitive in a frozen state, which is solely due to the collodion-cotton. In the soft gelatinous state, of course, every shock is annihilated, and the gelatins are in fact indifferent in this state; but when the gelatin is frozen and forms one rigid, hard mass, a blow will be readily communicated throughout the whole mass, and the collodion-cotton will be the first to explode. It is therefore of high importance that the nitroglycerin or dynamite should never be allowed to freeze during manufacture. Even in moderately warm rooms the cold earthenware taps may cause freezing, or drops of nitroglycerin spilt on the floor may become hard, and the danger of working frozen dynamite in cartridge presses is very great. It has repeatedly happened that small crystals of frozen nitroglycerin “cracked” on a wooden floor by being rubbed with a leather shoe.

The sun has a decided effect on the nitroglycerin, inasmuch as the heat generated will decompose it. This is the reason why the roofs and windows should be painted white, especially the window-panes, as they will usually contain some faulty spots which act like lenses. The action of the sun on nitroglycerin that had been inadvertently allowed to run away in the sand has several times produced explosions.

The refuse resulting from the sweepings, the residues on the filters, the mud in the deposit of washings, etc., have to be carefully burned. This refuse, or even defective dynamite, if laid out in a train and ignited, will burn quietly for some time, but then suddenly explode. The author is indebted to Dr. Dupré, F. R. S., for the hint that by pouring paraffin oil over such refuse it can be burnt without fear of explosion.

Although all the possibilities of danger have not been mentioned, and although perhaps the long list may have alarmed you, yet the author confidently asserts, from personal knowledge and long experience, that the manufacture of dynamite is far less dangerous and certainly less subject to sudden and unforeseen accidents than that of gunpowder, which has a record of casualties for more than five centuries.

Smokeless Powder.—The manufacture of smokeless powders has within the last four years come to the foreground, and is in many instances similar to that of the gelatin-compounds. As it is a comparatively new industry, chiefly in the hands of governments, and as none of the powders can yet claim to have reached the stage of perfection, it may seem to be superfluous to enter into many details. The fact that nearly every factory has some process of its own, because every one is anxious to keep his own experiences secret, makes general remarks very difficult.

Smokeless powders are practically of two kinds, those made from gun-cotton and a solvent only, and those made from nitroglycerin and gun-cotton with or without the aid of a solvent. Of late nitrated starch seems to be favored. As a solvent, acetone is now generally used, and the process of dissolving the gun-cotton, or making a gelatin of nitroglycerin and soluble gun-cotton, with or without the subsequent addition of insoluble gun-cotton and camphor, does not want any special allusion, as the machines for incorporating the materials are about the same as now used for the manufacture of blasting gelatin. But the subsequent working up into small square sheets or round disks, in imitation of the manufacture of certain pastries, requires more attention, although it must be said that the acetone, of which traces always remain in the powder, renders it comparatively safe. The jelly-like incorporated mass when leaving the mixing machine is subjected to a partial evaporation, and then passed through steam-heated rollers to be rolled into sheets, and at the same time to evaporate all the acetone. In these rollers small local explosions sometimes take place, which are probably due to some undissolved gun-cotton being submitted to heat and friction, but which pass away without doing any harm. Great care has to be taken to collect the acetone vapors, as they are explosive and may spread over a large area. The cutting of these sheets into small squares is also without special risk, as the pressure on the sheet is small, and no undue friction is likely to occur. Of course the powder should not be allowed to accumulate, as, although considerable quantities of it can burn without explosion, yet the fire spreads quick enough to cut off escape, as has been proved at a fire in an Italian factory. The manufacture of cordite, the British smokeless powder, varies in some stages from that of others, and being the invention of Sir Frederick Abel, and manufactured under his superintendence, does not call for further remark in this paper on the dangers of explosives.

The stability of smokeless powders with regard to atmospheric and climatic influence has still to be conclusively tested.

Other Explosives.—Nitrobenzene is, I believe, no longer used with explosives; its manufacture is well known, and is only dangerous during the nitration and through the poisonous effects of its fumes.

The manufacture of picric acid is also to a certain extent outside the scope of this paper. It presents no danger, during the manufacture proper, but the finished product, when mixed accidentally with certain materials, as lime, nitrate of lead, etc., will produce a detonating mixture, as has been successfully proved by Colonel Majendie and Dr. Dupré in their report about an explosion in Manchester.

Under the name of "Melinite," "Lyddite," "Ecrasite," etc., picric acid has been used for filling shells. Picrate of ammonia, trinitro-cresol and the ammonia salt of it are also used. They are melted in a hot water bath and filled into the shells. They are exploded generally by a primer of gun-cotton. As this work is only carried out in military establishments, further consideration is not necessary before this Society. Neither is it necessary to enter into the details of manufacture of roburite, securite, ammonite and similar products, or fireworks. The processes used with the former are very much the same as those used in other manufactories of explosives. In the manufacture of fireworks the preparation of the different mixtures, the compression into rockets, the distribution of pills for amorces, etc., can with little modifications be governed by the considerations applicable to gunpowder factories. Only the frequent use of chlorates, especially Chertier's copper, calls for attention as the cause of many decompositions, and all chlorate mixtures are extremely sensitive to shock and friction. Of course, if the mixture is moistened to form a paste, it will stand a great amount of shock, but when too much water is added, some particles may become exposed to the direct action of the blow.

The last explosive to be mentioned, before discussing the dangers in conveyance and use, is fulminate of mercury, which is used for filling caps and detonators. The manufacture is simple enough, and with ordinary precaution no accident should happen. Of course the ebullition after the addition of alcohol has to be carefully regulated, and attention has to be paid to the way the developing vessels are carried about, the fume-pipes put on, etc.; the nitrous ether formed should also be condensed away from fire. The washing of the fulminate should be well attended to, to avoid decompositions,

and the ready-made fulminate should be stored with not less than 20 per cent. moisture. It is chiefly in the working up of the fulminate where the danger comes in. As to drying it, the ordinary precautions as to heating by a current of air, absence of metal in the room, having hair rugs or india-rubber mats on the floor are sufficient.

The mixing of the fulminate with nitrates, chlorates, ground glass, etc., is perhaps the most dangerous part, as thereby a large amount of friction is produced. The process used at Woolwich is certainly the safest, and will give a better mixture than the usual work with a feather. It consists essentially of a silk bag on which there are diagonally placed india-rubber disks, like a string of pearls. To the bottom of this bag is fastened a thread, which is moved by a lever from behind an iron screen, thereby taking up and throwing down the fulminate between the disks. No explosion has happened at Woolwich since the introduction of this ingenious mechanism some years ago.

The filling of caps with the fulminate is done everywhere by carefully planned machines, which avoid friction and overcharging. The compression of the priming composition is best made in molds attached to separate weighted levers for each cap, so that in spite of the probable inequality of filling, each charge should only receive the same pressure as the other. In some factories the whole press is sheltered by a screen which is automatically closed during the compression, and no composition is allowed to be in the room.

In fulminate factories proper precautions must be taken against any possible friction. These are briefly the use of hair rugs, felt slippers, frequent washing and dusting of floors and rugs, preventives against spilling of material, etc. Like other mercury substances, fulminate is injurious to the body, especially the gums of the teeth, if too much dust is produced and ventilation not efficient.

This is the only country, to the author's knowledge, in which the exclusion of iron from the interior of the buildings, the absence of so much as a few grains of mud or grit on a floor, and in general the cleanliness throughout are rigorously enforced. It certainly made a great stir amongst the manufacturers when the Explosives Act came into operation, but seldom was there on the whole a wiser measure taken. If one remembers that last year only in one gunpowder factory were there fatal accidents, and that the mortality amongst the workmen in explosives factories was not larger than that in all London, you will agree with the author that the Explosives Act was

very beneficial and that the inspectors who carry it out are doing most useful work. It is certainly not the absence of a little grit, because in thousands of cases it will be of no harm, but the general spirit of the order, cleanliness and precaution instilled to the workmen which makes a factory safe.

According to the Explosives Act, every danger building must be provided with an efficient lightning conductor. In spite of the Lightning Rod Conference, in which so many eminent men took part, the question as to what forms an efficient lightning conductor is yet undecided. A lightning conductor is a good and useful instrument on a dwelling-house where an accidental disturbance in the arrangement may not do great harm, but the case is entirely different with a workshop or a magazine for explosives. The thorough and reliable examination of a lightning conductor can only be done by an electrical expert, and in a factory where sometimes 100 of them have to be tested this takes several days. Yet, if a gale is blowing, or the factory is exposed to the influence of sea-atmosphere, the lightning conductor is soon out of order again. Then take the presence of machinery in the buildings, tram-lines, pipe-lines overhead and underground, and you will find that a lightning conductor is not only a very limited preventive, but very often a positive danger. Without further entering into this question, the author thinks that a competent investigation of this subject with reference to explosives factories would be very beneficial.

A great many factories are now lit by electricity. Since this paper was written, special regulations in regard to electric lighting in explosives works have been issued by the Home Office. I do not wish to criticise these regulations, as too short a time has elapsed, and their effect cannot yet be appreciated. I will therefore only give my own experience. It is highly important that suitable lightning conductors should be attached to the circuit. From experience, the author knows of two cases where the lightning struck into the wires, which were carried overhead. The wires should always enter a building from opposite sides, so as to prevent accidental short circuits, and no joint or switch should be allowed inside the building. The lamps should invariably be surrounded by a tightly fitting large glass globe, which allows sufficient radiation of the heat. Although the heat on the outside of the lamp is scarcely larger than 120° , yet, if a lamp be covered with explosive dust and the heat cannot radiate into the open air, there will be such an accumulation of heat that serious accidents

may occur. As to an excess of tension in the current, the best plan is to have an arrangement whereby in case the tension rises over a certain limit the whole of the plant is cut out of circuit. It is by far preferable to have the place in darkness than to see sparks traveling along the wires.

It would be quite possible to write a paper by itself about the dangers in connection with the use of explosives in mines. Miners will frequently insist on treating explosives with the greatest recklessness, and if it were not as a rule accompanied by a loss of life or limbs, I would be able to write quite an amusing paper about the innumerable ways in which the miners handle explosives. Carrying gunpowder in open boxes, with a candle on the hat or in the hand, squeezing detonators with the teeth, charging bore-holes with boring bars, thawing dynamite on a hot stove, or even on an open fire, in a straw hat, are cases that frequently occur. It will still take a long time before anything like proper precaution will be taken everywhere.

The carriage of explosives, whether by road, vessel, or rail, is under ordinary circumstances free from danger. No explosive is licensed which does not in itself present a certain degree of safety, and the packing is so substantial that unless the packages are very roughly handled not even a spilling of explosive is likely to occur. For this reason, in almost every country the carriage of explosives by rail is allowed. Of the more important countries, Great Britain alone makes an exception as regards gun-cotton and dynamite, but why cannot be said. The railways will carry gunpowder, detonators, blasting gelatin and gelatin dynamite, but not gun-cotton and dynamite. Gun-cotton is always sent with from 20 to 30 per cent. moisture, in which state it cannot be exploded by ordinary means. Dynamite is no more dangerous than gelatin dynamite, and in the 20 years during which it has been carried on Austrian railways not a single accident has occurred. Let us hope that here also this obstacle will soon be removed; it injures the railways indirectly more than anybody else, as they are the largest consumers of coal and iron, which cannot be won without the use of explosives.

In discussing this paper Mr. Arnold Philip said that some 18 months previously, in going over a large dynamite works, he had seen a plant employed for the recovery of the acids which had been used in the manufacture of nitroglycerin. This apparatus consisted in part of two scrubber towers, apparently built of flags

of sandstone held together outside by iron tie-rods; inside they contained coke or some other suitable material on which to condense the acid fumes. The waste acids were heated in stills connected with the scrubbers; there was, however, some difficulty in employing this apparatus, for explosions were not infrequent. These explosions were usually slight in character, and chiefly occurred in the scrubbers, but they caused considerable financial loss by the damage which they caused to this part of the plant. All the trouble was due to the minute amount of nitroglycerin which remained in the waste acids even after they had been allowed to stand and settle for a very considerable time. On account of this difficulty there was a natural disinclination on the part of the manufacturers to distil waste acid, and it was not at all an uncommon thing in nitroglycerin factories for tons of it to be thrown away. If, however, these traces of nitroglycerin could be satisfactorily removed, the acids might afterwards be recovered, and a great saving thus introduced. It was possible that this might be done by dissolving out the trace of nitroglycerin by means of paraffin. Of course the strength of the acids in question made it quite impossible to employ either hydrocarbons of the benzene series or ether for this purpose. With regard to the question of lightning conductors, it would be interesting to know whether Mr. Guttman had had any experience with Prof. Oliver Lodge's method of protecting buildings; this was based on the same principle on which electrometers were sometimes shielded by wire cages. Professor Lodge proposed to cover buildings with what was practically a network of galvanized iron wire. This material was of course far cheaper than copper or any copper alloy, and although not so good a conductor, yet for electric discharges of such high potential as lightning, so long as there was a metallic conductor, it really mattered very little whether it had a high or low conductivity.

Mr. de Mosenthal said that he believed that Dr. Dupré's experiment with the broomstick was correct only so far as chlorate of potash explosives were concerned. Referring to the question of lightning conductors, an explosion due to lightning had occurred quite recently in a manufactory on the Continent, where the rod had been examined by an expert a few days only before the explosion occurred, and was therefore probably in perfect order. In that case the conductor was placed on the earthworks which protected the building, but it was generally supposed that the position of the con-

ductors was immaterial. As Mr. Guttman had pointed out, very little was known about the subject; and it was to be hoped that the report of a Special Commission which had been at work in Germany for something like two years would throw further light on the subject.

Lieutenant-Colonel Cundill remarked that last year only one fatal accident had occurred due to the manufacture of explosives. He thought that statement spoke volumes for the care exercised by the manufacturers. His department was much indebted to the trade for the way in which any suggestions made by them before the Explosives Act came into force had been carried out. The average number of deaths in England and Wales alone caused by explosions in manufacture in the seven years preceding the introduction of the Act was 39.5; the average was now something under eight for the United Kingdom. In 1890 there were eight deaths, but those were all in one factory; and the accident which caused the one death in 1891 was due to a man hammering a cast-iron die-plate with a steel punch in a building where there was gunpowder, this being a flagrant violation of the statutory rules.

After some observations from Mr. Otto Hehner, Mr. Guttman in reply said that the suggestion of Mr. Philip to use paraffin for effecting the better separation of nitroglycerin from the waste acids had not, to his knowledge, been tried with nitroglycerin, but it had been tried with picric acid. He knew of a case where it had been used for many years for separating the picric acid, but he had recently seen a sample of a compound which had been found during such separation, which was a dangerous one. He had been asked to make experiments with this substance as an explosive, but it smelt so decidedly acid that he requested that it should be taken back as soon as possible and washed. He had carefully considered Professor Oliver Lodge's system of lightning conductors. The idea, however, was not new. A Belgian (Mr. Melsens) was the first to make lightning conductors in that manner. Professor Zenger, of Prague, had developed it, and it had been extensively tried by the Austrian military authorities. In that country, in the mountain region of the Karst, a thunderstorm occurred nearly every day, and the lightning struck everything above ground. They had a number of exposed forts and military stores there, containing gunpowder, ammunition, ready-made shells, etc., and it was not a pleasant feeling to find these things exposed to such thunderstorms. They had

tried the wire-cage system and it was found to be a very effective protection. Colonel Ph. Hess placed in such a cage one of the bridge detonators employed for military purposes, which are so sensitive that the smallest amount of electricity would fire them, and he could not get an explosion although he applied the sparks of a Wimhurst machine. So far no more had been heard about the practical application of this system. As to Mr. de Mosenthal's observations, he would just mention that the broomstick question had been discussed in that room by Dr. Dupré. If he remembered rightly, it was in connexion with kinetite, an explosive which it had been attempted to introduce in this country. For a long time the English government would not pass it, on the ground that it was not safe. This the agent of the firm who introduced the explosive tried, in that room, to explain was not the case. He remembered reading Dr. Dupré's speech on that occasion, in which he stated that everything in the hands of a man who was willing went all right, but that if any person who was not conversant with the matter struck the substance with a broomstick on a wooden floor it would go off. He believed that any explosive which Dr. Dupré had tested did not fail to explode when struck with a broomstick. Lastly, he would deal with Mr. Hehner's observations. He (Mr. Guttmann) had often discussed the question of glycerin with Mr. Hehner, and he was aware that Mr. Hehner held that a small quantity of chlorine, acid, or aldehydes in glycerin was not very important; yet he believed he expressed the opinion of manufacturers when he stated that they held the opposite view. Mr. Hehner had said that experience was the principal thing to be taken into consideration, and the experience of manufacturers showed that the presence of chlorine developed hyponitric acid, a body the formation of which they desired to avoid as much as possible. The same remarks applied to aldehydes and poly-glycerins. It was probably these constituents that formed the amount of organic matter in the residue. If one per cent. of organic matter was present in the residue, there was sure to be a smaller yield of nitroglycerin and a larger development of nitric peroxide.

In his study of the "Explosive Properties of Trinitrotoluene," C. Hausserman has made various experiments to test the safety and suitability of this body as an explosive, and he states that there are no difficulties and dangers in its manufacture which could hinder it from entering the field with other explosives. In order to test its stability

when kept for some time he exposed portions of this body in the air for several months to varying temperatures (-10° to $+50^{\circ}$), and found that when the trinitrotoluene had been crystallized from alcohol, only a slight surface yellow color was noticed, and no change could be detected in any of its other properties; but when the body had only been freed from acid by washing with water and dilute soda and allowed to stand a short time, traces of acid vapors were frequently detected by the "heat test." Some of the trinitrotoluene was rubbed in an iron mortar, alone and mixed with sand, and no change was observed. On striking it on an anvil, only a very slight decomposition could be detected, and this did not give rise to a report or any appearance of fire. Further experiments showed that trinitrotoluene could not be exploded by flame or by heating in an open vessel in the air. Heated on platinum foil it first melts, then evaporates and catches fire, burning quietly with a very sooty flame. Projected on to a red-hot iron plate it simply burns rapidly. When heated in a test-tube it boils at 300° , and if the heat be continued it froths up and catches fire, leaving a large porous carbonaceous residue. Only when a large mass is rapidly heated in a covered vessel does feeble detonation take place, and this produces very slight effects. Seventy grammes of the powdered substance were placed in a closed cubical zinc case, the sides of which measured 4 cm. This case was placed on a cast-iron plate 2 cm. in thickness, and was fired by a fulminate detonator 35 cm. in length. The explosion was accompanied by a loud report and a distinct, although faint, cloud of smoke. The iron plate was quite destroyed and pieces of it scattered widely. Further experiments showed that it belongs to the class of shattering explosives. A mixture was also made of 1 part of trinitrotoluene and $3\frac{1}{2}$ parts of ammonium nitrate. Comparative experiments showed that this mixture did less mechanical work on explosion than the trinitrotoluene alone, but more than a corresponding mixture of dinitrobenzene and ammonium nitrate. It is pointed out that the manufacture of an explosive by mixing trinitrotoluene and ammonium nitrate does not give rise to injurious fumes, as in the case of dinitrobenzene.—*J. Soc. Chem. Ind.*, **10**, 1028; 1891.

Berthelot and Matignon (*Compt. rend.*, **113**, 246-249), in studying the Heats of Combustion and Formation of Nitrobenzenes, have obtained the following results;

	Heat of combustion, constant volume. Cal.	Heat of combustion, constant pressure. Cal.	Formation from elements. Cal.	Formation from nitric acid. Cal.
Orthodinitrobenzene	+704.6	+703.5	+0.5	+58.3
Metadinitrobenzene	+698.1	+697.0	+6.8	+64.8
Paradinitrobenzene	+696.5	+695.4	+8.4	+66.4
Trinitrobenzene (1:3:5)	+665.9	+663.8	+5.5	+90.9
Trinitrobenzene (1:2:4)	+680.6	+678.5	-9.2	+76.2

It is clear that although the values for the various isomerides are very similar, as is usually the case, there are distinct differences, amounting to 1 per cent. in the case of dinitro-derivatives, and to 2 per cent. in the case of trinitro-derivatives. The differences are also distinct in the case of the formation from nitric acid, and the heat developed becomes less the more advanced the substitution.

The heat of formation of a nitro-derivative is always but slightly different from that of the generating hydrocarbon; and it follows that the oxygen of the nitroxyl group has nearly the same combustible power as if it were in the free state. Since the heat of formation becomes less as nitration advances, it follows that the combustible energy of the oxygen gradually increases. The bearing of this result on the explosibility of nitro-derivatives is obvious.

A. Huber, in studying the Physiological Action of Dinitrobenzene (*Virchow's Archiv*, **126**, 240-270), finds that the main effects of dinitrobenzene, as tested on both cold- and warm-blooded animals, are changes in the blood, paralysis and intense dyspnœa. The blood becomes of a dark chocolate color; the red corpuscles are largely deprived of their pigment, which in frogs partly collects round the nucleus. Spectroscopic investigation showed an absorption band in the red, reminding one of the similar band of acid hæmatin, and of methæmoglobin, but not identical with either. It is spoken of as the dinitrobenzene band, and it is considered that this compound acts in a specific manner on the blood pigment. After large doses, the urine was found to be brown in color, and to contain a strongly reducing substance, and sometimes dinitrobenzene was itself present. The body temperature is lowered. The illness which workers in roburite factories suffer from appears to be caused by dinitrobenzene fumes.

"The Explosive Properties of Ammonium Nitrate" have been examined by C. A. Lobry de Bruyn, and from the results published in *Rec. Trav. Chim.* we extract the following:

Ammonium nitrate is a component of many explosives which are but slightly sensitive to ordinary mechanical shocks, and are difficult of ignition, although by the detonation of small quantities of mercuric fulminate they are rendered explosive. Berthelot (*Abstr. J. Chem. Soc.*, p. 453; 1882) and Thorpe (*Trans. Chem. Soc.*, p. 220; 1889) prove that endothermic combinations decompose explosively under the influences of mercuric fulminate, and it is well known that explosives require a variable initial impulse to cause their decomposition. The author describes the following experiments which were made with shells of 8 cm. caliber, weighing 7 kilos., and capable of holding about 200 grammes of explosive. The force of the explosion was estimated by the number and weight of the collected pieces and the distance to which they were scattered; the difference between this weight and the original weight being reckoned as shell reduced to powder by the explosion. In the case of black gunpowder fired electrically by a platinum thread, 10 pieces were collected whose collective weight was nearly that of the original shell, but, when a fulminate cap was used, 77 pieces whose collective weight was but 3.8 kilos. was obtained. When shells filled with bellite, dynamite, and cotton-powder were exploded by means of 1 gramme of mercuric fulminate, the shells were reduced to powder. One gramme of mercuric fulminate produced no effect on a shell filled with ammonium nitrate, except to evaporate a small amount in the immediate vicinity of the fuse, whilst the screw holding the shell was moved. Three grammes of fulminate caused a low, rumbling explosion, and 62 pieces of shell were collected which weighed 6 kilos. A shell containing 180 grammes of ammonium nitrate and 20 to 30 grammes of bellite (composed of dinitrobenzene 1 part and ammonium nitrate 4 parts) yielded, on explosion by 1 gramme of mercuric fulminate, 230 pieces weighing 2.75 kilos. Hence it appears that ammonium nitrate requires a stronger initial impulse than either dynamite or dry cotton-powder; that its employment, unless it be mixed with charcoal or aromatic nitro-compounds, is negatived on account of its weaker action, although for coal-mining purposes its employment would seem to be advantageous, as but a slight rise in temperature accompanies the explosion.—*J. Chem. Soc. Abstr.*, 683; 1892.

Among recent works are to be noted “*Études de Tactique*,”* by General Lazeux, which deals with the consequences of the adoption

* pph. 8vo, 63 pp. L. Baudoin et Cie., Paris, 1890.

of smokeless powder and of rapid-fire, small-caliber guns; "La Fortification Permanente et les Explosifs en 1890-1891,"* by Capitaine G. de' S., which treats of the effects of nitro-substitution explosives in shell on fortifications, giving the results of experimental trials; "Die gepresste Schiesswolfe,"† by Franz Plach, which is an excellent brochure on the properties, preparation and methods of using military gun-cotton for torpedo work, and is especially novel in its illustrated description of the means of forming charges for the heads of auto-mobile torpedoes from service blocks; "Blasting,"‡ by Oscar Guttmann, which devotes some 60 pages to the properties of modern explosives and contains descriptions of a new apparatus for testing the force of explosives; "Miner's Pocketbook,"§ by C. G. Warnford Lock, which gives some useful information on explosives for mining; and "Machines pour fabriquer la poudre,"|| which is a trade catalogue.

* pph. 8vo, 63 pp. Henri Charles-Lavauzelle, 1892.

† pph. 1g. 8vo, 133 pp. 24 ill. Pola, 1891.

‡ 1g. 8vo, 179 pp. 136 ill. Charles Griffin & Co., London, 1892.

§ 472 pp. Spon & Chamberlain, N. Y., 1892.

|| pph. 8vo, 52 pp. 14 ill. Grusonwerk, Magdebourg-Buckau.

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NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XXV.

Under the title "Modern Gunpowder Tests," A. Tenner gives in the *Amer. Field*, 40, 527-530, 552-555, 576-577, 600-601, Dec. 1893, the results of tests which were recently conducted at Chicago and at the DuPont Works at Carney's Point, N. J., and which had for their object the determination of the relative merits of several of the "nitro-powders," now in the market or recently offered for use, when fired from shot guns of various kinds, in comparison with certain well known black sporting powders.

The qualities especially tested, upon which the relative values of the powders were believed to depend, are enumerated in the following table, the maximum weights assigned to each being placed opposite.

QUALITIES AND POINTS OF MERIT.

Qualities.	Points of Merit.
1. Comparative lowest bursting strain.....	30
2. Uniformity of bursting strain.....	15
3. Highest velocity (penetration).....	20
4. Uniformity of velocities.....	14
5. Best pattern with a sufficient corresponding velocity.....	25
6. Uniformity of pattern if accompanied by sufficient velocity.	14
7. Non-susceptibility to moisture.....	15

*As it is proposed to continue these notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address, *Columbian University, Washington, D. C.*

	Quantities.	Points of Merit.
8.	Non-susceptibility to dry heat.	15
9.	Least fouling of barrels.	8
10.	Least recoil.	8
11.	Least smoke.	8
12.	Least heating of barrels.	5
13.	Least liability of causing a corrosion of gun barrel.	15
14.	Least degree of reaction to highly increased charges.	8

The values as assigned the powders tested are exhibited in the next table, the numbers at the head of each column conforming to that for qualities in the preceding table.

POINTS OF MERIT AS AWARDED TO EACH POWDER.

Powder.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Total	Order
American Wood.	29	12	16	11	23	13	12	0	13	6	6	4	5	4	154	5
S. S.	26	10	18	10	22	14	12	4	9	7	6	6	5	4	153	8
DuPont's smokeless.	18	6	19	11	24	11	12	5	11	8	8	8	4	5	150	9
Schultze.	24	10	18	10	23	10	14	5	9	7	6	6	8	4	154	5
Schultze, Pompton.	24	8	20	9	23	14	14	5	8	7	6	6	7	4	154	5
DuPont's black.	30	14	20	11	21	10	15	11	13	1	3	0	8	2	159	4
E. C.	28	11	18	13	25	11	14	7	11	6	6	6	6	4	166	3
Walsrode, leaf.	26	13	17	14	21	14	17	15	15	8	6	6	6	4	172	2
Walsrode, grain.	26	14	18	14	25	11	11	14	13	8	8	8	5	5	180	1

The velocities were determined in the ordinary way at 40 yards, with the Boulengé chronograph. The Hahn spring pressure gauge was used for chamber pressures. The author claims that recoil is better calculated from "several formulas," than determined by experimental observation, and hence he has employed the former method but he fails to give these formulas or the data used.

The hygroscopic properties of the powders were tested by exposing them in open dishes for twenty-four hours in a cellar where the relative humidity was 85 per cent. The amount of moisture absorbed being as follows :

HYGROSCOPIC QUALITIES.

American Wood.....	7.00 per cent.
S. S.....	4.00 “
Schultze, Pompton.....	3.40 “
Schultze.....	3.25 “
E. C.....	2.50 “
DuPont's black.....	2.25 “
Walsrode, grain.....	2.25 “
Walsrode, leaf.....	2.00 “
DuPont's smokeless.....	2.00 “

The author considers velocities of between 800 and 900 feet at 40 yards the best for shot guns. Less than 700 will not kill; more than 900 give a bad pattern. Judged by this criterion all of the above powders except the two Walsrode and the DuPont black were worthless after exposure to moisture as above described.

The effect of drying was tested by exposing in a closed oven to a temperature of 205° F. for one hour, cooling and then loading with normal charge; the results are shown in the following table in which is compiled the mean pressure of these powders under normal conditions and their highest pressures, after exposure to heat, in pounds per square inch.

DRY HEAT TEST.

Powder.	Normal Mean Pressure.	Highest pressure after heating.
American wood.....	6,145	7,159.6
DuPont's black.....	7,203	7,908.3
E. C.....	7,584	9,011.1
Walsrode, grain.....	8,402	9,231.6
Schultze.....	8,894	9,408.0
S. S.....	8,313	10,249.9
Schultze, Pompton.....	10,995	12,539.1
DuPont's smokeless.....	9,510	14,700.0

The author holds that while a bursting strain of 12,000 pounds to the square inch may be considered comparatively safe, yet such a pressure is certainly too high to be endured by the average gun for any length of time. “A gas pressure of 10,000 pounds may be considered to have reached the highest point of safety for a continuous charge.” Judged by this criterion the last three powders must be rejected.

It should be said that in compiling the column of "Normal Mean Pressure" great difficulty has resulted from the fact that the experimenter has varied more than one factor in a single experiment of a comparative series and we may add that he also fails to note the grades of the various powders tested.

The tests of primers with the Smokeless, Eley, Winchester Rival, Rival No. 3, Nitro Club, Kynoch, and U. S. Rapid, gave the first place to the Smokeless.

The "Composition of Certain Modern Powders," is given by Charles E. Munroe in *J. Am. Chr. Soc.* 15, 1, 1893, the powders analyzed belonging to the so-called nitro-powders, and all being claimed to be more or less smokeless. The "volatile," (hygroscopic moisture) was determined by drying over calcium chloride to constant weight. The dried samples were then digested in ether-alcohol, somewhat diluted, filtered through a weighed asbestos filter, (prepared by filling a drawn out tube with asbestos exhausted by ether-alcohol and ether), which was immersed in a beaker with ether-alcohol, washed until solution ceased and dried to constant weight. The soluble cellulose nitrates (nitro-cotton) was determined by precipitation from the ether-alcohol filtrate with three volumes of chloroform. The ether-alcohol-chloroform filtrate was evaporated and the salts present determined. The residue insoluble in ether-alcohol was extracted with boiling water, the metallic salts present determined, dried, weighed, again exhausted with ethyl-acetate and the lost by the last exhaustion noted as "gun cotton." The nitro-glycerine was determined in a Soxhlet extractor together with traces of resins or oil. When the powder was readily attacked by water the aqueous treatment preceded the ether-alcohol treatment and the salts present were extracted together with the "humus," which latter was determined by treating the residue, from evaporation of the aqueous solution, with repeated doses of nitric acid, again evaporating to dryness and gently fusing. To determine the aurin the sample was exhausted in a Soxhlet extractor with chloroform, the tared flask weighed with the residue; the residue taken up with a few drops of chloroform, transferred to a separatory funnel, shaken with strong ammonia water and separated. The chloroform solution was thus repeatedly washed with dilute ammonia until no pink color was developed in the water, then again evaporated in the tared flask and the weight of the residue determined. The difference in the two weights is aurin.

Nitro-cotton..... Gun-cotton Cellulose..... Paraffine..... Barium nitrate..... Sodium nitrate..... Potassium nitrate..... Aurin Soluble nitro-lignin..... Insoluble nitro-lignin... Lignin (charred) ... Humus..... Aurin (alk.)..... Graphite..... Phenyl amidazobenzene. Sodium carbonate..... Nitro-glycerin..... Volatile..... Total.....	Schultze Gunpowder.		Per cent.	27.71 32.66 1.63 4.20 27.62 2.88 2.17
	E. C. Gunpowder.		Per cent.	53.57 1.86 3.12 .. 34.26 3.67 1.48 0.55
	American Wood Powder, Grade C.		Per cent.	.. .. .. .. .. 15.27 ..
	American Wood Powder, Grade E.		Per cent.	.. .. .. .. .. 17.81 ..
	American Wood Powder, Ten Bore Trap.		Per cent.	.. .. .. .. .. 14.82 ..
	American Wood Powder, Twelve Bore Trap.		Per cent.	.. .. .. .. .. 13.38 ..
	American Wood Powder (No mark).		Per cent.	.. .. .. .. .. 9.76 ..
	Brackett's Sporting Powder.		Per cent.	.. .. .. .. .. 19.76 ..
	S. K. Powder.		Per cent.	20.39 57.73 18.08 .. 1.24
	S. R. Powder.		Per cent.	28.18 46.97 19.97 2.35
	Rifleite Gunpowder.		Per cent.	22.48 74.16
	Maxim Powder (flat grains).		Per cent.	8.14 71.19
	Maxim Powder (cord).		Per cent.	6.84 46.60
	German Smokeless Powder.		Per cent.	48.83 7.45
				1.48 1.17 3.01 3.86 2.36 3.14 5.83 2.93 1.43 1.45 0.84 0.19 0.26 0.53

Eng. Pat. 19,068, Nov. 4, 1891, has been granted C. H. Curtis and G. G. Andre for the following "Improvement in the Manufacture of Gunpowder": Gun-cotton (trinitro-cellulose), generally containing about 12 per cent. of nitro-cellulose soluble in ether-alcohol, is mixed with 6-16 per cent. of dinitro-cellulose and manufactured, while wet, into pellets; or the usual process for making gun-cotton is so modified as to produce a nitrated cellulose containing 18-28 parts of the dinitro to 88 parts of the trinitro-compound, which is then made into pellets. The pellets are dried and treated with a solvent capable of dissolving only the dinitro-cellulose, which is thus made to thoroughly impregnate the trinitro-cellulose and to bind it together in hard, unfriable granules when the solvent has evaporated. This hardening process differs from those previously suggested, in that they only serve to harden the surface of the granule, and leave it friable. By varying the proportion of dinitro-cellulose within the above mentioned limits any requisite degree of explosiveness may be obtained, for the larger the proportion of dissolved cotton present, the slower the rate of combustion. By dissolving nitro-glycerin in the solvent used for the dinitro-cellulose, this explosive may be combined with the new gunpowder. Suitable proportions are 44 parts, by weight, of trinitro-cellulose and 12 parts, by weight, of dinitro-cellulose, with or without 40 parts, by weight, of nitro-glycerin.—*J. Soc. Ch. Ind.* 12, 63; 1893.

Eng. Pat. 15,865, Aug. 22, 1893, has been granted F. G. and P. S. DuPont for "Improvements in and relating to the Manufacture of Smokeless Explosives," which consists in a method of granulating gun-cotton by mixing a solvent, such as nitro-benzene, with gun-cotton held in suspension in a fluid, such as water. On agitation, the solvent has a tendency to seize the particles of gun-cotton, forming in the water a more or less coherent mass. By adding the solvent in proper proportions a well-defined granular condition results. These grains afterward undergo a process of hardening by rotation in a barrel, and removal of water and solvent contained in the grains by heat. The violence of the explosive may be modified by varying the duration of these processes or by dissolving from $2\frac{1}{2}$ to 10 per cent. of a moderating agent, such as nitrated rosin or nitrated turpentine, in the solvent before mixing

with the suspended gun-cotton. The specification is illustrated by drawings of the apparatus and in the processes.

Eng. Pat. 15,866, Aug. 22, 1893, issued under the same title to the same parties, states that increased hardness and consolidation of the above described grains may be obtained by subjecting the grains to the actions of a gentle heat, not sufficient to cause vaporization of the solvent, but to remove some of the water condensed in the grains, the grain having the property of giving up its condensed water before it parts with the solvent used in its preparation, and at a lower heat.

Eng. Pat. 15,867, Aug. 22, 1893, issued under the same title to F. G. DuPont, describes an improvement on the two preceding patents which consists in emulsifying the nitro-benzene or other solvent before adding it to the gun-cotton suspended in water. By this procedure a more uniform granulation and a more complete precipitation of the nitro-cellulose is produced than when the unemulsified solvent is used. A solution of soap or sodium carbonate in pure water may be employed for producing the emulsion with the solvent.—*J. Soc. Ch. Ind.* 12, 1057; 1893.

M. E. Leonard's "Smokeless Powder," according to Eng. Pat. 20,066, Oct. 24, 1893, issued him for "An Improved Gunpowder", consists of nitro-glycerin, gun-cotton, lycopodium, and a neutralizer of free acid, such as urea or dinitro-benzol. The most satisfactory proportions for the U. S. 30-calibre rifle are found to be

Nitro-glycerin	150	parts by weight.
Gun-cotton	50	"
Lycopodium	10	"
Urea crystals	4	"

For great guns, where a further deterring and moisture-proof effect is desired, 7 parts, by weight, of cotton-seed oil are added to the above-named ingredients.

"Improvements in Methods of Securing the Chemical Stability of Nitro-Compounds" forms the subject of Eng. Pat. 22,384, Nov. 22, 1893, granted R. S. Schipphaus, it being claimed that this results from the addition of a suitable quantity of urea after the

nitro-compounds have been freed from acid as far as possible by washing. The urea is added in the form of a solution in methyl or ethyl alcohol.

Lieut. Willoughby Walker, 5th Artillery, U. S. A., gives in the *J. U. S. Art.* 2, 374-382, 1893, under the title "A New Powder," the results of a powder prepared in the Laboratory of the U.S. Artillery School and designated 3 P. P. G. The composition of the powder is not indicated, but the statement is made that "after the final proportions of the ingredients were determined and the methods of manipulation adopted, scarcely a shot was fired the result of which could not have been foretold. In the few instances of what might possibly have been classed as abnormal results, the causes leading thereto were readily discovered, and were directly attributable to the difficulty attending the manufacture of the powder by hand."

To subject the method "of controlling the pressures to as rigid a test as possible, from the same incorporation, several lots of powder were subjected to varying degrees of the same general method of manipulation, and subsequently made up into cartridges. In every instance did the pressure respond to the treatment, ranging for the same charge of 42 grains from 25,500 to 47,800 pounds per square inch.

"As was expected, the velocities varied correspondingly, but one appeared invariably a direct function of the other, so that the operator at the rifle, upon reading the pressures, knew immediately the velocity within ten feet per second; and, conversely, the operator at the chronograph knew the pressure, within 100 pounds per square inch, as soon as he took from the tables the velocity corresponding to the reading of his instruments."

Eng. Pat. 20,880, Nov. 17, 1892, to A. H. Dumford, for "An Improvement in the Treatment of Nitrated Cellulose for the Manufacture of Explosives and other Compounds containing Dissolved Nitrated Cellulose," seeks to obviate the necessity of drying nitrated cellulose before dissolving it for the purpose of making explosive compounds, by first squeezing the wet nitrated cellulose and then treating it with a "dehydrator" capable of dissolving water, such as alcohol, or preferably a solvent of the nitrated cellulose, acetone being preferred in the case of trinitro-cellulose. A slight rise in

temperature occurs during this treatment. When much water is present the operation may have to be repeated. The residual product is pressed to remove the dehydrator and dissolved water. Trinitro-cellulose is left in a putty-like condition when a solvent, such as acetone, is used as the dehydrator. The dehydrator can be separated from the dissolved water by distillation.

F. C. Glaser, in Eng. Pat. 23,105, Dec. 15, 1892, for "Process for Manufacturing Powder suitable for Practice, Ammunition, Sporting Cartridges and similar Purposes," seeks to make any explosive suitable for service ammunition more voluminous and porous by incorporating with it 20 to 40 per cent. of a soluble or volatile body, such as potassium nitrate, benzene, or paraffin oil, which has no decomposing or dissolving effect on the explosive, then making the parts into suitable forms by known means, and then removing the solvent or volatile body by boiling the grains in water or other solvent, or by evaporation.

A remarkable "Explosion of Pyroxyline" is described by C. O. Weber in *J. Soc. Ch. Ind.* 12, 117; Feb., 1893: The complete removal of the free acids from pyroxyline being essential to its stability and the removal of the last traces being an exceedingly tedious operation, Dr. Weber sought to accomplish this result more speedily by washing with a small quantity of ammonia until the yellow color, indicative of alkalinity, had appeared, drying between filters and finally in an oven at 70° C., but during the latter operation, after about three hours exposure, and while the temperature was still at the point fixed, the gun-cotton exploded with sufficient force to tear the copper oven to pieces.

This explosion appears remarkable from two points of view: First, that it should have occurred with the dinitro-cellulose, which is scarcely regarded as an explosive, and, second, in the low temperature at which it took place, it being much below even that at which gun-cotton (hexa nitrate) ignites, between 160° and 170° C. In fact, testing pure dinitro-cellulose, Weber found its point of ignition between 194° and 198° C.

Some years ago, Weber pointed out that if we attempt to evaporate on a water-bath a concentrated solution of ammonium nitrate to which a small amount of acetic acid has been added, when we reach a certain concentration the whole mass ignites and the reac-

tion is almost explosive in its violence. This reaction is largely employed in a practical way in the sulphuric acid industry, small quantities of ammonium sulphate being added to expel traces of nitric acid, and in both cases the hydrogen of the ammonia is burned at the expense of the oxygen of the nitric acid.

Weber finds in this reaction the explanation of the explosion, the ammonia used in washing forming an ammonium nitrate, but, not being used in sufficient quantity, a trace of free acid remained to react with the nitrate in the warm oven.

H. Kolf has been granted Eng. Pat. 22,739, Dec. 10, 1892, on "Improvements in the Manufacture of Gunpowder," which consist in first impregnating a nitrated carbo-hydrate material (which may be treated if desired with a solution of an alkaline sulphite) with a solution of an alkaline nitrate, subsequently drying it, and afterwards mixing it with nitro-sugar, nitro-treacle, or nitro-glycerin, the mass being thus heated to about 40° to 60° C., so as to obtain a partially gelatinous mass, which is reduced to a completely plastic form by simply rolling, kneading, or pressing it, after which it can be moulded into any desired shape.

Through the courtesy of Col. Majendie, R. A., we are in receipt of the 17th *Report of H. M. Inspector Explosives*, 1893, forming a volume of 169 pages, which is replete with information of interest and value to readers of these notes. Among them, we note the following explosives authorized during the year: Amberite No. 1, consisting of purified nitro-cellulose mixed with nitro-glycerine, paraffin and shellac. Amberite No. 2; nitro-cellulose mixed with barium and potassium nitrate and paraffin, vaseline or graphite. Cannonite No. 1; gun-cotton with nitrates and rosin. Cannonite No. 2; gun-cotton with rosin. Fortisine; saltpeter, sulphur and charcoal with dinitro-benzene and rosin or dextrine.

Experiments made with .303" cartridges proved that, whether loaded with black powder or cordite, when capped they were entirely free from liability to explode *en masse*, but that they were liable to so explode when uncapped.

Experiments on setting fire to 2500 lbs. of cordite stored in a brick building with slated roof, heated to 100° to 120° F. proved that, while there was rapid combustion, "there was no explosion in the ordinary sense of the word," though the whole mass was consumed

in about seven seconds and the "roof of the building had been lifted almost bodily off, and had fallen to one side and collapsed." The greater part of the débris was comprised in a radius of 12 yards.

The report of Dr. Dupré shows that all of the 35 samples of dynamite No. 1 tested passed; of the 5 samples of blasting gelatine, 3 were rejected; of the 35 samples of gelatine dynamite No. 1, 4 were rejected; and of the 57 samples of gelatine dynamite No. 2., 6 were rejected.

The annual record of accidents and outrages, both English and foreign, which is an admirable feature of these excellent reports, occupies 42 pages and includes not only those in which explosives (properly called) were involved, but also many of those resulting from petroleum. In addition, in Appendix W, twenty-four pages are devoted to a detailed tabular view of the 149 accidents by fire or explosion occurring in 1892.

The carelessness shown in thawing dynamite has led to the preparation of Appendix X, giving a detailed tabular view of the seventy accidents occurring from this cause in the United Kingdom since 1871-72.

Circulars regarding the electric lighting of factories; the precautions to be adopted in the manufacture of nitro-benzole, etc.; the packing of colored fires; the precautions to be taken by users of frictional signal lights; and directions to inventors of explosives who seek entry in Great Britain, are a few among the many important subjects treated of.

Special Rept., CVII., of *H. M. Insp. Exp.*, Dec. 30, 1893, on an "Explosion at F. Joyce & Co.'s Ammunition Factory," is also received. This explosion occurred in the mixing of mercury fulminates with ground glass, potassium chlorate, and antimony sulphide, to form a cap composition, the mixing being done by shaking the powdered ingredients gently together on a sheet of paper, and then passing through a sieve in the usual way. The exact origin of the explosion is not determined, but the process is considered by Col. Majendie to be in itself a sufficient cause, and the process meets with his condemnation. He recommends that the "jelly-bag" system of mixing used at Woolwich be adopted.

Through the courtesy of Gen. H. L. Abbot, U. S. A., we are in

receipt of the three "Reports of the Board of Ordnance and Fortification," Nos. 1 and 2, being issued respectively as Ex. Doc. No. 12, 1st Session, and Ex. Doc. No. 11, 2d Session, of the House of Representatives of the 52d Congress, while the 3d appears as a publication of the War Department. Included in these are the reports of the experiments on high explosives for use in shell charges and of smokeless powders.

In the first report it is recorded that Perunite, composed of nitro-glycerine, nitro-ethyl, nitro-methyl and pyroxyline, takes rank as the most powerful explosive tested, the force of the following according to the sub-terra trials being :

Perunite B	17.57
" C	15.61
" D	13.66
Explosive gelatine	10.00
Rackarock	9.36
Emmensite	5.49
Gun-cotton	3.16
U. S. rifle powder	1.72

A scheme for testing explosives for safety, permanency, strength and sensitiveness is given, the novel feature being the proposed rotating machine for determinating the danger of premature explosion from the rotation of shells induced by the rifling.

In the second report, Americanite is rejected as a shell charge.

In the third report Americanite is condemned, and Rackarock in the normal proportions is found to be unsafe. Justin's system of loading explosive gelatine is found meritorious, as far as it has been carried, and it has been demonstrated that wet gun-cotton and emmensite may be safely used as service charges in the 12-inch mortar shell. The most important need now is a proper detonating fuse.

In "The Determination of the Relative Sensitiveness of Explosive Substances Through Explosions by Influence," *J. Am. Ch. Soc.*, 15, 10; 1893, Charles E. Munroe says: "The determination of the sensitiveness of explosive substances has already been made by a number of different methods, but it is yet a question as to the real value of these results. Thus, we have the methods by percussion,

by heat, by friction, and the like. It has occurred to the author that a much more delicate and reliable method would result from the application of what has been termed by Berthelot 'explosion by influence.' What is meant by this term is the explosion of a secondary mass through the explosion of a primary mass which is separated from the secondary mass by a definite interval. Numerous observations have been made, as notably in the Danish experiments, on explosions of this kind taking place under water, and a great many instances are recorded of similar explosions being brought about on the surface of the earth; but the submarine experiments were made with a limited number of substances confined in envelopes which materially modified the results, while the earth experiments were made under continually varying conditions. In his experiments he employed a continuous and, as nearly as may be, homogenous medium, through which the effect of the explosion of the primary mass was conveyed to the secondary mass, while he used definite and moderate quantities of explosives under constant conditions of confinement—circumstances which are easily repeated, while the attending phenomena are easily observed.

The method pursued was as follows :

The initial and secondary masses were placed upon a wrought iron armor plate nine feet five inches long, three feet four inches wide, and one inch thick, which rested upon a second plate of the same material and dimensions. As these plates had been made for use on vessels of war, they contained several lines of rivet holes and were curved to the shape of the vessel. This, of course, affected the rigidity of the system, and it was expected that it might introduce irregularities into the results, but firing trials made under otherwise similar conditions showed that for the masses of explosives used the results were uniform at all points.

The initial mass consisted of 100 grams of explosive, while the secondary mass varied from 30 to 100 grams, it being evident that the weight of the secondary mass had no effect on its initial sensitiveness, and that it was essential only to have a sufficient quantity to produce a positive and visible effect on the firing plate in case it was exploded.

In the experiments for testing the relative sensitiveness of different explosives when referred to a common standard, 100 grams of

United States service gun-cotton was selected for the initial mass because it was the most accessible, convenient and constant one at hand, but apart from these considerations there is an advantage in using this as the initial mass, since it has been shown by Abel that gun-cotton is the most efficient detonating priming agent among explosive substances.

The gun-cotton, as issued from the Naval Torpedo Station where it is manufactured, is in the form of blocks two and nine-tenths inches in diameter, three and seven-eighth inches in diagonal (the corners being chamfered), and two inches in height, and it is made by compressing pulped gun-cotton in molds by means of a hydraulic press, the pressure applied being about 6500 pounds per square inch. The blocks are pierced through the center with a hole seven-sixteenth inch in diameter in which the detonator is to be inserted for firing. This gun cotton was steam-dried before using, and pieces of 100 grams weight were cut off by cutting transversely to the vertical axis, so that the diameter of the base of these pieces was that of the blocks from which they were taken.

As all the other explosives were in the form of either a powder or paste, it was necessary to provide containers for them, and these were made from well calendered manilla paper. When these explosives were used for the initial mass, the boxes had the same form and dimensions as the service block of gun-cotton, except that the corners were not chamfered, and hence the area of the surface in contact with the plate was very closely the same as for the gun cotton. When these explosives were used as secondary masses they were enclosed in similar open paper boxes, but they were but 5.58 centimeters in diameter. In all cases, the explosive was evenly distributed over the bottom of the case and brought well in contact with it, so that the area of the face of these different explosives in contact with the firing plate was as nearly as possible identical. It is evident from this description that the explosives were tested when unconfined except from atmospheric tamping.

In making the test it was of course necessary to proceed in a purely tentative manner. A point was selected upon the plate where no breaches of continuity were apparent for a considerable range, the initial mass was placed upon the plate and at the outset of each series two secondary masses (one being placed on

either side of the initial or primary mass and at unequal distances from it) and the primary one detonated. When this was detonated it produced a well marked impression on the iron, and the same effect was observed in the case of the secondary masses when they were detonated, the effect, however, being in all cases diminished as the secondary mass approaches that point at which it ceased to be detonated. The observations were most easily made when gun-cotton was used for both the primary and secondary charges, for when the secondary charge was not far beyond the limit at which secondary charges could be detonated, it burst into flame and was tossed into the air in this inflamed condition through the disturbance produced in the atmosphere by the detonation of the initial mass.

When non-detonating or sub-detonating explosives were used for the secondary charges, impressions were produced so long as explosion was effected, but the impressions produced, at least near the extreme limit, were due only to the removal of scale from the plate by the shock of the explosion and to the deposition of soot and other products. When beyond this limit the explosive was found scattered upon the plate together with fragments of the containers.

As the limit was approached, single secondary charges only were used with each initial charge in order to simplify the observations. The points measured were from the inside edge of the primary mass to the inside edge of the secondary mass before explosion.

The results obtained were as follows, with 100 grams of gun-cotton as the initial charge the following were the maximum limits at which detonation took place :

Gun-cotton.....	10 c. m.
Explosive gelatine, (camphorated).....	20 “
Judson R. R. P.	25 “
Emmensite, (No. 259)	30 “
Rackarock.....	32 “
Bellite.....	50 “
Forcite, No. 1.....	61 “
Kieselguhr dynamite, No. 1	64 “
Atlas, No. 1.....	74 “

These were rather unexpected results as they were at variance with the prevailing idea that the nitro-substitution powders were less sensitive to sympathetic explosion than any others. When the same explosive was used for both the initial and the secondary charges, the following results were obtained:

EMMENSITE ON EMMENSITE.

Initial mass.	Secondary mass.	Distance.	Result.
100 gms.	30 gms.	10 c. m.	Exploded.
100 "	30 "	11 to 30 c. m.	Failed.

ATLAS ON ATLAS.

Initial mass.	Secondary mass.	Distance.	Result.
100 gms.	30 gms.	11 to 30 c. m.	Exploded.

FORCITE ON FORCITE.

Initial mass.	Secondary mass.	Distance.	Result.
100 gms.	30 gms.	11 to 15 c. m.	Detonated.

KIESELGUHR DYNAMITE ON KIESELGUHR DYNAMITE.

Initial mass.	Secondary mass.	Distance.	Result.
100 gms.	30 gms.	11 to 30 c. m.	Detonated.

Circumstances prevented the further carrying out of these experiments, but it is to be hoped that some explosive expert with a large theoretical as well as a practical experience will take them up, as they undoubtedly will lead to results of practical interest.

Lieutenant C. de W. Willcox has cleverly translated for the *J. U. S. Artil.*, 2, 408, 1893, a very valuable paper, by Colonel Ritter U. von Wuich, appearing in the *Mitt. Art. Genie-Wesens.*, No. 2, 1891, on the "Combustion Temperature of Explosives."

Although accepted but provisionally, and regarded with skepticism, the calorific intensities recorded in our literature, and upon which subsequent calculations are based, are for black gunpowder 3000°–4000° C., gun-cotton 5000°–6000° C., nitro-glycerin 7000°–8000° C. The most obvious objection offered to the adoption of these figures is that even the lowest of them is above the melting point of gun metals.

Discussing the data of Noble and Abel, Bunsen and Schischkoff, E. Wiedemann and others, von Wuich finds, at the outset, that a cardinal error in these estimations or determinations consists in

assuming that the specific heats of the products of combustion are independent of the temperatures of the products, and using, in consequence of this view, constants which had been determined at the freezing point, whereas von Wüch finds it evident, from simple logic based on the phenomena of nature, that thermal capacity decreases as the quantity of heat in a given body increases.

He then proceeds to estimate the specific heats of the products at the higher temperatures, and applying his results he finds that, whereas, when calorific intensities, or, as he styles them, combustion temperatures, are obtained with specific heats determined at 0° C., he gets 3340° C. for gunpowder, 4893° C. for trinitro-cellulose, and 7240° C. for nitro-glycerin; using his newly-developed expression for the specific heat, he obtains 1874° , 2516° and 3005° C. for gunpowder, gun-cotton and nitro-glycerin, respectively.

The following conclusions have been reached by H. B. Dixon in his investigation of the "Rate of Explosion in Gases" (*Eng. and Min. J.*, 55, 129, 1883):

1. Berthelot's measurements of the rates of explosion of a number of gaseous mixtures have been confirmed. The rate of the explosion wave for each mixture is constant. It is independent of the diameter of the tube above a certain limit.

2. The rate is not absolutely independent of the initial temperature and pressure of the gases. With rise of temperature the rate falls; with rise of pressure the rate increases; but above a certain crucial point variations in pressure appear to have no effect.

3. In the explosion of carbonic oxide and oxygen in a long tube, the presence of steam has a marked effect on the rate. From measurements of the rate of explosion with different quantities of steam, the conclusion is drawn that at the high temperature of the explosion wave, as well as in ordinary combustion, the oxidation of the carbonic oxide is effected by the interaction of the steam.

4. Inert gases are found to retard the explosion wave according to their volume and density. Within wide limits an excess of one of the combustible gases has the same retarding effect as an inert gas (of the same volume and density), which can take no part in the reaction.

5. Measurements of the rate of explosion can be employed for determining the course of some chemical changes.

In the explosion of a volatile carbon compound with oxygen, the gaseous carbon appears to burn first to carbonic oxide, and afterward, if oxygen is present in excess, the carbonic oxide first formed burns to carbonic acid.

6. The theory proposed by Berthelot—that in the explosion wave the flame travels at the mean velocity of the products of combustion—although in agreement with the rates observed in a certain number of cases, does not account for the velocities found in other gaseous mixtures.

7. It seems probable that in the explosion wave: (1) the gases are heated at constant volume, and not at constant pressure; (2) each layer of gas is raised in temperature before being burnt; (3) the wave is propagated not only by the movements of the burnt molecules, but also by the heated but yet unburnt molecules; (4) when the permanent volume of the gases is changed in the chemical reaction, an alteration of temperature is thereby caused which affects the velocity of the wave.

8. In a gas of the mean density and temperature calculated on these assumptions, a sound wave would travel at a velocity which nearly agrees with the observed rate of explosion in those cases where the products of combustion are perfect gases.

9. With mixtures in which steam is formed, the rate of explosion falls below the calculated rate of the sound wave. But when such mixtures are largely diluted with an inert gas, the calculated and found velocities coincide. It seems reasonable to suppose that, at the higher temperatures, the lowering of the rate of explosion is brought about by the dissociation of the steam, or by an increase in its specific heat, or by both these causes.

10. The propagation of the explosion wave in gases must be accompanied by a very high pressure lasting for a very short time. The experiments of MM. Mallard and Le Chatelier, as well as the author's, show the presence of these fugitive pressures. It is possible that data for calculating the pressure produced may be derived from a knowledge of the densities of the unburnt gases and of their rates of explosion.

A. Mitscherlich has studied the "Ignition Point of Gaseous Mix-

tures" (*Ber.* 26, 399, 1893), and for a mixture of hydrogen and oxygen, in the proportion of 2 : 1, by volumes, he found the point of ignition to vary with the pressure and with the shape of the containing vessel. Under the same conditions, and for pressures less than 760 mm., the temperature of ignition fell in direct proportion to the decrease of the pressure of the gaseous mixtures.

For pressures higher than 760 mm. the only conclusion that could be drawn with any degree of certainty from the experiments was that the point of ignition of gases is higher when they are compressed than when they are not, which is contrary to hitherto accepted views.

Free hydroxylamine, NH_2OH , has been isolated by M. Lobry de Bruyn (*Recueil des Travaux Chimiques des Pays-Bas*, 10, 101, 1891), the free base being obtained as follows: About a hundred grams of hydroxylamine hydrochloride, $\text{NH}_2\text{OH} \cdot \text{HCl}$, were dissolved in 600 cc. of warm methyl alcohol. A quantity of sodium dissolved in methyl alcohol was then added, in such proportion that the hydrochloride was present in slight excess over and above that required to convert it to sodium chloride. After deposition of the separated sodium chloride the solution was decanted and filtered. The greater portion of the methyl alcohol was next removed by distillation under the reduced pressure of 160–200 mm. The remainder was then treated with anhydrous ether, in order to completely precipitate the last traces of dissolved sodium chloride. The liquid eventually separated into two layers, an upper ethereal layer, containing about 5 per cent. of hydroxylamine, and a lower layer containing over 50 per cent. of hydroxylamine, the remainder of the methyl alcohol, and a little dissolved salt. By subjecting this lower layer to fractional distillation under 60 mm. pressure, it was separated into three fractions, of which the first contained 27 per cent. of hydroxylamine, the second 60 per cent., and the third crystallized in the ice cooled receiver in long needles. This third fraction consisted of free solid NH_2OH . Hydroxylamine, as thus isolated in the free state, is a very hygroscopic substance, which rapidly liquefies when exposed to air, owing to the absorption of water. The crystals melt at 33° , and the fused substance appears to possess the capability of readily dissolving metallic salts. Sodium chloride is very largely soluble in the liquid; powdered

nitre melts at once in contact with it, and the two liquids then mix. Free hydroxylamine is without odor. It is heavier than water. When rapidly heated upon platinum foil it suddenly decomposes in a most violent manner, with production of a large sheet of bright, yellow flame. It is only very slightly soluble in liquid carbon compounds, such as chloroform, benzene, ether, acetic acid, and carbon bi-sulphide. The vapor attacks corks, so that the solid requires to be preserved in glass stoppered bottles. The free base appears also to act upon cellulose, for, upon placing a few drops of the melted substance upon filter paper, a considerable amount of heat is evolved. The pure crystals are very stable, the base in the free state appearing to possess much greater stability than when dissolved in water. The instability of the solution appears, however, to be influenced to a considerable extent by the alkalinity of the glass of the containing vessel, for concentrated solutions free from dissolved alkali are found to be perfectly stable. Bromine and iodine react in a remarkable manner with free hydroxylamine. Crystals of iodine dissolve instantly in contact with it, with evolution of a gas and considerable rise of temperature. Bromine reacts with violence, a gas being evolved explosively and hydrobromic acid formed. The nature of the gas evolved is now undergoing investigation. M. Lobry de Bruyn warns those who may attempt to prepare free hydroxylamine by the above method that it is a dangerously explosive substance when warmed to a temperature of 80° – 100° . Upon warming a flask containing the free solid base upon a water-bath a most violent explosion occurs. A spontaneous decomposition appears to set in at about 80° , and even in open vessels the explosion is very violent. Care must also be taken during the fractional distillation of the concentrated solution in methyl alcohol to cool the apparatus before changing the receiver, since, if air is admitted while the retort is heated, the experiment ends with an explosion.

Among recent works are to be noted “*Traité Théorique et Pratique des Matières Explosives*,”* by Léon Gody, which is a most satisfactory book for general readers. It contains, in a permanent form, the lectures given by the author at l'École d'Application and at l'École de Guerre. Naturally, as the author treats to some

*8vo, 480 pp. Ad. Wesmael Charlier, Namur, France, 1893.

extent of most of the explosive substances known, from black powder, pyrotechnics and liquid fires through the nitric ethers and nitro substitution products, to the endothermic organic and inorganic compounds that are rarely to be found outside the limits of the research laboratory, it follows that his treatment is not exhaustive. Unfortunately, the book, which is otherwise arranged and printed in a convenient and attractive form, is without an index.

In these Notes,* we have called attention at some length to the appearance of the third edition of Berthelot's "*Sur la Force de la Poudre*," and to the originality and importance of the book. Time has but emphasized its great value to students of explosives, hence, in order to render it accessible to a larger number of readers, C. Napier Hake and William McNab have, at the suggestion of Col. Cundill, R. A., translated it into English, condensing much, omitting the repetitions consequent on the form in which it originally appeared, and issuing it in a single volume in place of the two volumes of the original, under the title "*Explosives and their Power*."† The translators have not only translated the French of Berthelot, but they have rendered a greater service in translating the older chemical notation, which Berthelot persists in using, into the modern notation which is more generally understood, and they have added abstracts of Berthelot's later essays on the propagation of detonation in explosive gaseous mixtures and his studies on the "explosive wave" in solid and liquid bodies. The work of the translators is admirably done and the book is issued in very good form indeed.

"*Explosifs de Suréte Grisoutite—Wetter dynamites—Explosifs a Base d'Azotate d'Ammoniaque*,"‡ by A. Macquet, consists of two memoirs by the author, which are bound up with various documents from other sources. The matter is badly digested and arranged, and is evidently intended as an endorsement of grisoutite. There is a good deal of information regarding the dangers attending the use of explosives in fiery and dusty mines; the results of the experiments of the French and Austrian commissions

*PROC. NAV. INST., II, 275, 1885.

†8vo, 563 pp., 43 ill., John Murray, London, 1892.

‡8vo, 594 pp., Baudry & Co., Paris, 1893.

being given with the other documents ; and the relative advantages of various explosives proposed for use in such mines, is discussed, but it is difficult to get at the information on any particular topic, especially as the book lacks an index.

A. Pouteuax has added another book to the rapidly-increasing literature of smokeless powder, entitled "*La Poudre Sans Fumée et les Poudres Anciennes*,"* and though a book of some size, practically but little over thirty pages are devoted to modern smokeless powders, the rest of the space being given to black powder and its substitutes in the chlorate and picrate classes ; to methods of measuring pressures and velocities ; and to devices such as the pneumatic guns of various kinds ; all of which is more fully and exactly treated of in other works. The book has an index but it is a rather curious one.

Through the courtesy of Capt. Jas. M. Ingalls, 1st Artillery, U. S. A., we are in receipt of a copy of his "*Interior Ballistics*,"† a text-book prepared for the use of student officers at the U. S. Artillery School. As must be the case with text-books, the greater part of the matter is collected from other sources, which are properly cited by the author, but the chapters which deal with the behavior of the powder in the gun, the effect on the velocity of combustion of variations in the form and size of the grains ; the derivation of formulas for estimating the pressures and velocities consequent on the known characteristics of the powder, and allied topics, contain much original matter. The author modestly states that, with the exception of the original matter in these chapters, "he has simply culled, from various sources, what seemed to him desirable in an elementary text-book, arranged it all systematically, from the same point of view, and with a uniform notation," but he has succeeded in making a book which is well digested and arranged and in which the matter is presented in a clear and concise manner.

*8vo, 156 pp., Ed. Dubois, Paris, 1893.

†8vo, 158 pp., 2d ed., Artillery School Press, Fort Monroe, Va., 1894.

Through the courtesy of Lieutenant J. H. Glennon, U. S. N., now on duty at the U. S. Naval Academy, we are in receipt of a copy of his "Interior Ballistics, with a Short Treatment of the More Common High Explosives."* The methods followed in the treatment of the subject are an elaboration of those employed by the author in his article on "Velocities and Pressures in Guns,"† Sarrau's General Equation, which holds for but a particular case, being dropped, and simpler methods of calculation being used. Among other features, we note that the relations between breech and projectile pressures are given, problems on the recoil of the gun while the projectile is in the bore and on the initial velocity of recoil are solved, and attention is called to the fact that a pressure-gauge in the base of the shell does not, as ordinarily constructed, show the accelerating pressure. The methods used in finding the laws of the combustion of gunpowder are unusual, while the law for the combustion of an explosive, under variable pressure, is deduced by a novel method, suggested by the study of the velocity of escape of a gas through a vent. In the chapter on smokeless powders, the methods of solution of problems for these new ballistic agents are indicated, though complete data for the discussion of a variety of cases were unobtainable. It is pointed out that nearly all the early data on the firing of guns lacked precision in important particulars, and in this work we are supplied with formulæ through which, when the DeBange gas-check is used, the exact volume of the powder-chamber may be readily calculated.

*8vo, 153 pp. Deutsch Litho'g and Printing Co., Baltimore, 1894. Address U. S. Naval Institute, Annapolis, Md.

†PROCEEDINGS NAVAL INSTITUTE 14, 395-418; 1888.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

By CHARLES E. MUNROE.

No. XXVI.

Through the courtesy of Col. Majendie we are in receipt of the *18th Ann. Report of H. M. Insp. Exp.*, 1893, which, like their former reports, is replete with interesting and valuable information. It is impossible, with so voluminous a report, to do more than briefly allude to but a few of the interesting facts presented, and we note, first, that the importations of dynamite for 1893 are 90 per cent., of gelatine dynamite 9 per cent., and of matagnite gelatine 68 per cent. less than for 1892, while that of detonators is increased, over 7,179,000 having been brought in. In the required tests of explosives imported and sold, all the dynamite samples were very satisfactory, but of the plastic explosives the same cannot be said, as 33 per cent. of the blasting gelatine and 23 per cent. of the gelignite samples failed.

The danger from accidents with frozen plastic explosives, especially while thawing them, is dwelt upon at length, the admirable instructions of the Nobel's Explosive Company on this matter being given in detail, and it is stated by the latter that blasting gelatine may become congealed at temperatures as high as 45° F. without altering the soft and plastic outward appearance of the cartridges. In his report, Dr. Dupré says that while only three out of 78 samples of gelatinized preparations failed to pass the heat test, a far larger number came very near the limit,

*As it is proposed to continue these notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. *Address, Columbian University, Washington, D. C.*

and he again urges that both the nitroglycerin and nitro-cotton used in these preparations be purified to such a degree as to stand the heat test for a longer time than that required officially for each by itself. Mr. Hake, inspector of explosives in Australia, calls attention to the fact that certain grades of gelatine dynamite containing wood meal suffer considerably, as regards stability, during their passage from England, and the spontaneous explosion of over 17,000 pounds of blasting gelatine at Matoonga, Bombay, December 28, 1891, shows that their continued stability is not yet assured. Taking the facts of this accident with that at Aden in 1888, and probably certain others in India, it would appear that the destructive change in the explosive in such a climate is effected in three to four years.

Among the many accidents recorded is a very detailed and non-sensational account of the frightful explosion at Santander, Spain, November 3, 1893, from which it appears that about 33 tons of dynamite were exploded, 510 persons were killed and about 2000 wounded. A singular case was that of the explosion of about one ounce of nitroglycerin in the converter at Perranpath, Cornwall, September 5, 1893, due, it is believed, to the acids and nitroglycerin retained by the scale and rust accumulated in the bottom of the converter. The explosion of ecrasite in the laboratory of the Austrian War Office, August 1, 1893, while a projectile was being filled with it, is of especial interest to ordnance officers, though unfortunately no details are given. The accident at Waltham Abbey, March 2, 1893, was a remarkable one, since 4212 pounds of gun-cotton in the drying stove caught fire and burnt up without exploding, though 308 pounds at Ardeer, on October 27, 1882, under somewhat similar circumstances, produced a violent explosion.

The fire at Tangye's safety-fuze factory, August 10, 1893, furnished some interesting results, in that 144,000 feet (nearly 28 (?) miles) of "tube safety-fuze," containing one and one-half ounces of gunpowder to every twenty-four feet, were consumed without any explosion whatever.

The new explosives examined were westfalite, a mixture of ammonium nitrate and gum lac, Von Förster's powder, a pure nitro-cellulose thoroughly gelatinized and mixed with a little chalk, and Schnebelite, a powder containing a small percentage of potassium chlorate.

Through the courtesy of Dr. T. M. Chatard we are in receipt of a copy of his address as president of the Chemical Society of Washington, entitled "The Abuse of Explosives, with Suggestions for Preventive Laws."*

After describing the properties and methods of manufacture of the characteristic explosive substances, Dr. Chatard says:

All explosives, in their nature and mode of production, can be divided into a few classes; the processes of manufacture are in principle very simple; and all sorts of mixtures can be made which are easily exploded. Under such conditions it is evident that prevention of their vicious use is surrounded with peculiar difficulties in addition to those which are always met with in attempting to control the sale or use of articles for which there is a legitimate general demand.

Granting the necessity of legislation to prevent abuse of explosives, we may lay down the general principle that it cannot be made effective if it interferes unduly with legitimate manufacture and employment.

In all engineering work, high explosives, when used, are not luxuries, but necessities. Not only can work be done more cheaply by their aid, but often could not be done without them. Examples might be given, but it is perfectly well known that this necessity is absolute, and that the great development of the explosive business has been caused by the demand of the engineer. He requires that his explosives shall be safe to transport, store, and handle, certain and powerful in action, and that the combustion shall be complete, leaving no deleterious residues. To satisfy these requirements the manufacturer must employ all the resources of skill, and only well-managed works can produce reliable articles in an economical manner.

It is not believed that the abuse of explosives can be prevented by governmental inspection or supervision of manufacture, transportation, or even sale. The laws of France are most minute on these points, but do not prevent outrages. Legal regulation may and can protect the workmen, the inhabitants of a neighborhood, the transportation agents, or the traveling public. For excise purposes, supervision of sale may be necessary, but cannot prevent crime. Explosives purchased from legal dealers and strictly according to provisions of law may be unlawfully used; they may

* Bulletin No. 8, Chem. Soc., Washington, Gibson Bros., 1893.

be stolen from lawful possessors by intending evil-doers, or the latter can easily obtain the materials for making their own explosives. Nitric acid, an essential, has such extended uses that it can be bought at any druggist's. Nor is it necessary to purchase the acid, as it can be easily made by distilling a mixture of nitrate of soda and sulphuric acid, both of which are in common use among farmers for composts and other home-made fertilizers. It is also very likely that in most cases of carefully planned outrages the explosives would, in part at least, be made by the conspirators.

But although governmental supervision of manufacture, storage, transportation, sale and use cannot be relied upon to prevent the vicious use of explosives, still this supervision would be an important aid. Moreover, such supervisory control, if acting under acceptable regulations, can be made very beneficial to this industry, and would be welcomed by most of those immediately interested. Col. Majendie, in a most interesting and valuable report on the operation of the laws affecting the manufacture and handling of gunpowder, shows that the English powder-makers, far from objecting to a rigid system of control, were glad to record themselves in favor of it, if it were made reasonable and general, and then rigorously enforced.

The reason for this is plain. Arrangements for the protection of the works, the workmen, and the neighborhood cost money, both to introduce and to maintain. If one manufacturer endeavors to protect his works or workmen by special improvements, care and regulations, he will not be able to produce as cheaply as his competitors if the latter are permitted to work without restriction. The same thing is true in the case of transportation agencies and dealers. The former often find it necessary to make regulations governing the transportation of explosives, and should always be aided by the law in enforcing them.

Such regulations when made by private individuals or corporations are always difficult to enforce. Even when clearly made for their own protection, workmen often stubbornly resist them and try to evade them in every way, nor is it easy to punish disobedience when detected. Nor is the general public much superior in this respect. The cry of tyranny is raised, and the demagogue, in his glory, vehemently denounces these encroachments on freedom.

If this supervision is desirable, the law should be national and general, passed by Congress and enforced by the General Government. State laws, however good, stop at the State line, and the best intentions of local legislators are often paralyzed by representations that their action will "drive away business," "lose votes," or any other of the cant phrases. The present condition of the oyster industry in Maryland is an instructive lesson, for there a small minority of people, who being well intentioned but ignorant of their true interests, have successfully resisted every attempt to prevent them from killing their goose, to the damage of the interests of the entire State. The law should provide a certain *minimum* of regulation—should be a minimum law.

Before attempting to frame such a law, a careful investigation and study of the practical requirements should be made by a commission appointed for the purpose. It should be made clear to all those interested—manufacturers, railroad men, dealers, engineers, miners, quarrymen and other workers—that their opinions, advice and criticism are sought for and are welcomed; that no legislation will be recommended until its provisions and their practical effect have been thoroughly discussed and substantially agreed to by them; and that no more legislation will be attempted than that which they themselves consider as the minimum amount necessary for the general welfare and protection. Intelligent newspaper discussion will be especially valuable, for it will clarify the public mind and detect deficiencies and defects which might otherwise escape notice until a time when their discovery might inflict serious injury on the whole matter.

Having thus investigated the subject, the commission can present to Congress its conclusions in the form of a general law providing for this minimum amount of control. As this law will have been already thoroughly discussed, understood and approved, the final sanction should be easily obtained. A law thus carefully framed should need but little machinery for its enforcement. Regulations suitable and acceptable to each branch of the business can, in the light of the previous investigations, be easily made under its provisions, and when officially promulgated would be binding on all. Methods of procedure against offenders should be simple, direct and summary.

Any serious attempt to prevent the vicious use of explosives will, however, compel us to go further, but in the same direction.

We must have a national and general license law, under which the *simple, unlicensed possession* of any explosive, except those especially excluded, shall be punishable. The excluded explosives should be fireworks and ordinary gunpowder, either loose or in cartridges. Fireworks are sufficiently well looked after by local authority, and any attempt to interfere, in this manner, with the use of gunpowder will result in failure. We must not attempt the impossible; what is possible will be hard enough to attain. The wording of the licenses will have to be varied to suit the circumstances; but, in fact, but few forms will be necessary. They should be obtainable at the least possible cost, with the least possible inconvenience; and the granting of them should not be discretionary, but be under rules clearly laid down. Discretionary action in this connection is wholly unnecessary and would be injurious.

How such a law would work in practice will best be shown by considering some particular cases. A chemist desires to carry on an investigation in explosives. He personally presents his written application, giving whatever information the general regulations may require, and receives his license. This entitles him and his assistants under his direction to do whatever work he may desire within the limits of his laboratory, but does not permit him or any one else to carry his explosives outside of those limits, or even to take them to some other place for further experimentation. For this purpose another form of license, equally easily obtainable, should be required. These restrictions interfere in no way with his scientific or practical work, but do aid in protecting the public.

Now let us consider the mining industry. If the license system will work well in that branch of engineering, it ought to in any other. A new mine is to be opened, and somebody is put in charge of the work. When it becomes necessary for him to procure explosives he goes to the nearest licensing office, files an application, which, again, is made out according to a prescribed form, and on payment of a very small fee receives an appropriate license. This license confers upon the licensee the right to store and use explosives upon the mining property, the name, location and limits of which are sufficiently nearly described in the license. Outside of those limits the license is entirely void. Included, but in express terms, is the permission to purchase explosives of any

kind or in any quantity, whenever and wherever the licensee may desire, and to convey the same to the property, either from the dealers direct or from the most conveniently situated public transportation point. The license should be personal and non-transferable, should run for not more than one year from date, and then *absolutely* expire. Renewal, if desired, should be an entirely new transaction, which can occur during the life of the first license, which must, of course, be simultaneously surrendered and destroyed. There would be no increase of restrictions on the purchase of explosives in consequence of this license law. The dealer should not be required to know that the purchaser is licensed. If any sale restrictions are introduced, these should come through the operation of the general code of dealers' regulations, framed for their protection, as previously indicated.

In the same way the transportation agents need only require that the packages of explosives are properly prepared for shipment, according to their own special code. Their responsibility would be the same as at present and would cease with the delivery of the goods. As to the conveyance of the explosives from the dealer's store or the railway station to the mine, this should be covered by the license. Some regulation for wagon transportation may be necessary, but otherwise no special liability should attach to the teamster during *bona fide* transit.

The explosives having reached the mine, are issued to the miners for use. This use is covered by the license to the superintendent, who may, as at present, make whatever rules for its conduct he may deem advisable. Certain regulations, however, should be made obligatory by law. In some cases the miners are furnished with explosives at the expense of the mine; in others they buy them from the management as they do their oil, candles, etc. If, at the end of his shift, a miner has any surplus explosive, he must deposit this in an appropriate place, provided by the company, where he can get it at the beginning of his next shift. Whether he has purchased it or not should make no variation in this regulation. Under no circumstances should he be permitted to take explosives to his dwelling-place, even if this be within the limits of the mining property. His family and neighbors must be protected. As to carrying it outside of those limits, both superintendent and miners stand on an equal footing. Both are absolutely forbidden to do so. If work is to be done

on a neighboring property, another license must be obtained for this. If the general magazine is situated on the first property, the new license can permit conveyance from one place to the other.

There is no occasion for licensing the individual miners, nor should this ever be done. There should be but one license for any one place, and that should be issued to the superintendent alone. Only through his permission can any one, within the limits of the property, legally have possession of any explosive.

With some changes in language the mining license will serve for the needs of the farmer, who sometimes finds it advantageous to use high explosives for the removal of stumps and rocks, and for other purposes—within the limits of his farm he may use them; outside of it, not at all. A special form of license covering a certain district, say a county license, will be necessary for well-diggers and others whose work is in the form of jobs of indefinite duration and location. The same may be said of prospectors, whose mode of life and manner of work present peculiar difficulties in the way of control.

Having in this manner provided for the needs of all legitimate business, we can then insist that the unlicensed possession of explosives shall be punishable, without reference to the intentions of the transgressor. The law of the District of Columbia concerning concealed weapons is an example. A man may be arrested for some trifling offense, but it is found that he has upon his person a concealed weapon. He makes no attempt to use it, but he has it. When he is brought up for trial he may even be acquitted of the offense, but is fined \$50 or punished by an equivalent imprisonment for having the weapon. His intentions are not considered; the fact is sufficient for condemnation, and there is no appeal. Of course the previous arrest has nothing to do with this, except as having given the opportunity to ascertain the fact.

Some such summary proceeding will be necessary under the license law if this is to be effective. Inasmuch as there will be no reason for unlicensed possession, the proof of fact will be sufficient. As the licenses are local and limited, the chances of detection of illicit actions will be greatly increased, as the real licensees and the nature of their licenses will be generally known. Moreover, any licensee transgressing the limitations of his license becomes at once amenable to a punishment, which some of his neighbors at least will see to it that he gets. In offenses against

this law, evil intentions should be presumed. If their absence can be satisfactorily proven, then the punishment can be reduced to a minimum; but there should always be a punishment, which for many reasons should be an imprisonment, with or without a fine, but need not be heavy or severe.

Dynamite outrages are generally planned and the explosives procured some time in advance. The power of summary arrest for possession conferred by this law would much increase the chances of prevention, for it would only be necessary for some secret information as to this possession to reach the proper authorities to enable them instantly to arrest the offending parties. The finding of the explosive would be quite sufficient for condemnation without the necessity of exposing the informer. During the resulting imprisonment further investigation could be made, but one such arrest would probably prevent the execution of the plan by the others concerned. Again, if the penalty for simple possession be not made too severe, the probability of obtaining such secret information will be much greater. As the laws are at present, should any one of a group of conspirators be seized with remorse and desire to prevent an intended outrage, he can only do so effectively by betraying the criminal intentions of his fellows. He knows that if he does this he will probably be compelled to give public testimony upon which may depend the lives of others who have trusted him and who are probably no more guilty than he. Moreover, through this publicity not only must he undergo all the obloquy which society, while availing itself of his services, heaps upon the informer, but also expose himself to private vengeance. This he may well hesitate to do; but if such a man knew that by merely revealing the fact of possession the outrage could be prevented without exposing any one of his fellows to any greater punishment than that attaching to illegal possession, it is reasonable to suppose that useful pre-repentance would be more frequent. It is prevention, not punishment, that is to be sought for.

The power of summary action and arrest for possession is indispensable. The authorities should be empowered to act at once upon information, and no other warrant for search or arrest should be required. Secrecy and suddenness of action will have a far more paralyzing effect upon the dynamiter than any display of the majesty of the law, which it is his purpose and study to defy and make contemptible. To those who may object that such proceed-

ings would be too high-handed, unconstitutional, etc., it may be replied that it is time that some of the technicalities that have been carefully built up around our laws should be swept away and justice be less impeded. It is time that some change should be made in the principle that law-abiding people must wait until the vicious perform overt acts before any legal steps can be taken to restrain them, and that then these steps, to be legal, must be according to rules apparently framed to give the greatest amount of trouble and expense to the prosecutor and the greatest chance of escape to the offender.

We do not need very severe laws to check dynamite outrages. A law which is plain, just and simple—under which detection will be easy and punishment certain—will require no heavy penalties to make it effective, so far as mere unlawful possession is concerned, but any attempts to make a criminal use of explosives—any threats, verbal or written, to do so—any incitements, verbal or written, of others to make such use against anybody in particular or society in general, or an expressed approval of such actions, should meet with speedy and severe punishment, which no legal technicalities should be permitted to delay. Such things are done and said to disturb and terrify the public, and usually by persons to whom the certainty of close confinement at hard labor will act as an effective deterrent. The Johann Mosts, O'Donovan Rossas and Louise Michels of society would speedily find their occupations and themselves gone to the penitentiary, where their usefulness to the world would be much increased. Of course those who are entrusted with the execution of such a law must be especially watchful lest its purpose be perverted to a means for private revenge or persecution. These may occur in any branch of criminal law, but must always be suspected and looked for in this connection, since secret information must be so much depended upon. If their existence is proved, the offenders should be most heavily punished, and none of the technicalities impeding convictions for perjury in ordinary cases should be permitted to have any force here.

It has been said that the licenses should specify the use. This should be broadly considered. What is meant is that such misuses as killing fish with dynamite, explosions for amusement, etc., shall be absolutely prohibited, license or no license. They are either barbarous or wholly unnecessary.

The excluded explosives are fireworks and gunpowder. All desirable amusement and noise can be obtained by their use. It is true that quite as disastrous outrages can be perpetrated by the aid of gunpowder as by that of dynamite, but its employment has not such a terrifying effect upon the public, who are accustomed to its use, which they could not be deprived of even if this were desirable. The recent introduction of smokeless powders for sporting purposes brings in, however, new complications. These powders are from two to four times as powerful as ordinary gunpowder, and are quite as effective for outrages as any of the dynamite preparations. How far their use should be controlled would be a matter for special consideration, but a license ought to be required for their possession. Convenient as they are, they are not necessary either for sport or protection. The great hunters, such as Gordon-Cumming, had not even breech-loaders; the old flint-lock served our purpose at Bunker Hill and Bennington, and was more than we wanted at Bladensburg; while if any son of the Revolution, American or otherwise, will load up his ancestor's horse-pistols and shoot as straight as we hope the old man did, his burglar will be as completely *hors de combat* as if he had been operated on by the latest improvement in firearms.

In 1894 Senator Hawley introduced into the Sundry Civil Bill H. R. 5575, 53d Congress, second session, the following clause: "To enable the Secretary of the Treasury to investigate and report upon the importation, use, transportation and manufacture of high and low explosives, with the view of securing by legislation greater security to life and property, five thousand dollars."

Acting on this, the Secretary of the Treasury appointed Mr. West Steever, a lawyer of the District of Columbia, who, on January 1, 1895, rendered a preliminary report which appears as Ex. Doc. No. 181, 53d Congress, third session. Mr. Steever says:

"This preliminary report will be confined to the first of the four branches in which the proposed investigation was prescribed by Congress to be conducted, viz. the importation of high and low explosives from foreign countries into the United States. Owing to the fact that until of recent date the importation of explosives from foreign countries into the United States has been of an insignificant character, very little attention has been paid

by Congress to regulate or restrict their introduction into this country.

“The only legislation on the statute book relating to the subject of the importation of high explosives from foreign countries into the United States is the act of Congress approved July 3, 1866 (Stat. at L., Vol. xiv, p. 81), and forming sections 5353, 5354 and 5355, under the title of Crimes, and sections 4278, 4279 and 4280, under the title of Commerce and Navigation, of the Revised Statutes of the United States.

“Section 5353 is a ‘qui tam’ action, and prescribes, among other provisions, for the importation in passenger conveyances of certain high explosives which have long since been discarded for more modern discoveries and consequently may be considered absolutely as a dead letter. No conviction has ever been reported in the books under this section, and an indictment under it for the importation of the recently discovered explosives would certainly be quashed by any court before which it would be brought.

“Section 5354 makes the offense, in addition to the ‘qui tam’ feature as above, manslaughter, with term of imprisonment for a period of not less than two years. This law, for the same reason, would even be still more difficult to enforce, for the obvious objection that it would involve a criminal conviction for the importation of high explosives totally unknown when the act of Congress was passed, and which are the only explosives now known to commerce.

“Section 5355 prescribed a ‘qui tam’ action if these long since discarded explosives are not packed in metallic vessels surrounded by plaster of paris and marked ‘Nitroglycerin, dangerous.’

“It is hardly worth while discussing this section, as the described explosives no longer form a part of commerce, and modern science has found that there is no more dangerous mode of packing any high explosive than placing the same in metallic vessels, as prescribed in this section. As Berthelot declares that no explosive more powerful has yet been discovered than nitroglycerin (not combined with any other substance), and as it freezes at 12° (say 54° F.), it can easily be conceived how dangerous it would be to transport this explosive in the mode prescribed in this section. The exuding of nitroglycerin was sup-

posed to be the only cause of its being subject to premature explosion, and the plaster of paris surrounding the receptacle was supposed to render it innocuous, but this idea has long since been discarded. The great danger is undoubtedly by its liability to freeze, and in this state it will explode even without any perceptible cause to the human sense.

“Sections 4278 and 4279 declare that it shall not be lawful to transport the said explosives between any foreign country to a place in any State, Territory, or District of the United States, and between any place in one State, Territory, or District of the United States and a place in any other State, Territory, or District of the United States, or any passenger-vehicle, or any vessel or vehicle of any description upon land or water, except packed in a metallic vessel surrounded by plaster of paris, and marked ‘Nitroglycerin, dangerous.’ These sections are obsolete for the reasons already adduced, as explained in commenting on the criminal and ‘qui tam’ sections above.

“At the time of the passage of the above-mentioned act of Congress very little was known definitely in regard to the composition or action of high explosives. It is true that Nobel had discovered dynamite a few months previous, but the manufacture has not been so perfected as to make it an article of commerce, and I am satisfied that no court would entertain for a moment such a strain of the language used as would bring any of the modern explosives within the purview of the penal sanctions of the statute.

“It is now nearly thirty years since Nobel made this great discovery, which proved to be the first practical step in the development of the manufacture of high explosives. During that period changes amounting almost to a revolution in the art of war have occurred by its use, and its influence in the peaceful avocations of life has not been of less importance. We are, though, but on the threshold, and there is every probability of even still greater changes in the near future. The great problem heretofore existing is to find some means to control the pressure generated by a high explosive, while eliminating what is technically called its ‘work.’ It is claimed that this has been recently accomplished in England, and an engine in the form of a ram for pile driving has been constructed, in which explosive power is used instead of steam, and, though still crude in principle, the work for which it is used is done with surprising energy and is

far superior to the relative steam engine used for the same purpose.

“Section 4280 is a proviso that none of the preceding sections shall be so construed as to prevent any State, Territory, District, city, or town within the United States from regulating or prohibiting the traffic or transportation of those substances within their said limits, or from prohibiting their introduction within said territorial limits for sale, use, or consumption therein.

“In the case of *Bowman v. Chicago and Northwestern Railway Company*, these sections of the Revised Statutes were discussed by the Supreme Court of the United States. Mr. Justice Matthews delivered the opinion of the court in the following language (125 U. S., 484):

But sections 4278 and 4279 relate also to the transportation of nitro-glycerin and other similar explosive substances by land or water, and either as a matter of commerce with foreign countries or among the several States. Section 4280 provides that the two preceding sections shall not be so construed as to prevent any ‘State, Territory, district, city, or town within the United States from regulating or from prohibiting the traffic in or transportation of those substances between persons or places lying or being within their territorial limits, or from prohibiting the introduction thereof into such limits for sale, use, or consumption therein.’ So far as these regulations made by Congress extend they are certainly indications of its intention that the transportation of commodities between the States shall be free, except where it is positively restricted by Congress itself or by the States in particular cases by the express permission of Congress.

“I would beg, also, to state that in my investigation of the laws of the different civilized nations in regard to regulating the importation of explosives, all such laws are framed so as not to interfere with the local laws and ordinances in force at the time of the promulgation of the general law. It stands to reason that no general law can regulate the subject without taking into consideration such local laws and ordinances suitable to the different localities for which they are enacted. As much activity in effecting general legislation on this subject has been displayed in the past twenty years in Europe, I beg to submit an epitome of the laws of the leading nations which have more particularly regulated the importation of explosives within their limits, and which is hereunto appended and marked A.

“I regard the enactment of a law regulating the importation from foreign countries into the United States of both high and

low explosives as the first step toward 'securing by legislation greater security to life and property.' Perhaps no commerce between nations is so fluctuating as that of explosives. Statistics show that one year may differ entirely from another, both in quantity and kind, and this is governed by the variety of demand and supply created by new discoveries and inventions, subject to all the contingencies of human life in peace and war and which cannot possibly be foreseen by the home manufacturer. The past year is a fair index, as in the early part the importation into this country was confined almost entirely to the ingredient nitrates and glycerin, but latterly a large amount of high explosives have arrived on our shores.

"Taking these views into consideration, I would beg to submit, to be embodied into legislation in part or the whole, a bill 'to regulate the importation of gunpowder, nitroglycerin and other explosive substances,' which is herewith attached and marked Appendix B.

"The classifications in this bill have been made as closely as possible to those prevailing in Europe, due regard being paid to the recent discoveries and inventions. The picrate division is, perhaps, the greatest departure, and that has been caused by recent developments in the manufacture of that kind of explosive in France and other countries. The mode of packing is that which is insisted upon in Great Britain, and which has been adopted more or less, or recommended to be adopted, all over the Continent. As the classifications include only the foreign explosives, the packing of such does not affect that prevailing in the United States or imported packages after breaking bulk. I have purposely abstained from introducing in this bill the 'qui tam' features which prevail in our legislation, as no other civilized nation has adopted such in its regulations of the importation of explosives so far as I can discover after diligent search. While the bill creates no new offices, ample means are provided for elasticity in its enforcement in giving discretionary power to the Secretary of the Treasury to grant permits waiving compliance with the stricter regulations contained therein in case of war or like necessity.

"I am satisfied that if the provision of the proposed bill herewith recommended had been a law, or some other legislation of like character had been in existence at the time, that the dynamite

fiend, Alexander Keith (alias William King Thomas, alias William King Thomson, alias George S. Thomas, alias Garne) could never have perpetrated the diabolical crimes with which he has been credited. By shipping explosives from European ports to New York, and then having the same sent back for re-exportation on steamers on which he over-insured goods, he was enabled to hoodwink the police authorities of the eventual ports of departure, and it was only by an appalling accident at Bremerhaven, on the 11th of December, 1875, that his plan of wholesale murder was unearthed. A chest, which had previously made the voyage to New York and returned, and conjectured to contain about 1000 pounds of lithofracteur, while being shipped on board the Mosel is supposed to have slipped out of the hands of the carriers and then falling to the ground exploded with terrible effect. Over one hundred persons were killed and many others more or less injured. A hole 30 feet in circumference and 8 feet in depth was made in the solid stone pavement and soil beneath the quay, and parts of the decks of the Mosel and Simoon tugboat, lying alongside, were carried up in the air and thrown to considerable distances. Everything which presented any resistance was destroyed within 2500 feet. Considerable light damage was done within 10 miles, and the report of the explosion was distinctly heard at a distance of 55 miles from Bremerhaven.

“The author of all this destruction of life and property committed suicide, but confessed before his death that the case was furnished with a clockwork apparatus which was intended to be wound up at Southampton (England) and which, after eight days, would operate to cause the explosion. A quicker trip than usual at this time of the year or a breakdown, causing delay in the clockwork apparatus, might have transferred the scene of explosion to New York harbor instead of Bremerhaven, with still greater destruction of life and property. It is supposed that several steamers that never were heard from were sent to the bottom by this fiend in human shape and by means of like contrivance. It was discovered that his business connections were with leading bankers and manufacturers, and but for the Bremerhaven accident he might have continued his career of crime for an indefinite period of time. After the revelation made through the confession of this ingenious enemy of the human race, it was high time for the civilized nations of the world to take measures

to protect life and property from the machinations of such depraved scoundrels. In this international legislation the United States has lagged behind, I am convinced, not from want of sympathy in the objects to be effected by such legislation, but, owing to our system of dual government, rather from a morbid feeling of dislike to appear to interfere within the sphere of the jurisdiction of the sovereignty of the different States composing the Federal Union.

“I would beg also to call your attention to a still more recent catastrophe caused in great part by lack of needful legislation.” The writer here describes the Santander explosion, an account of which is given earlier in these notes from the report of H. M. Inspector of Explosives. He then remarks regarding the accident:

“A glance over the provisions of the legislation as recommended herein will show that an accident inflicting such extensive damage would be impossible to occur at any port of the United States, owing to the restriction of 50,000 pounds to a single cargo imported, as prescribed by the proposed enactment.

“I could add to the above other accidents, almost countless in number, which have occurred from the want of regulations in regard to the importation of explosives and which have forced the civilized nations of the earth into the line of legislation recommended herein, but such relation would be of superfluous weight in argument, as no opposition is anticipated from any quarter. The cost of ocean freight has steadily declined since the regulations as to packing explosives have been understood and enforced by the leading commercial nations of Europe. Before these regulations and restrictions became law, few vessels would accept any cases of explosives as part of their cargo, and, consequently, the rates of freight on such articles were absurdly high, but such regulations and restrictions being enforced by fines and imprisonment, gave confidence to the carrier, and the supply of tonnage soon was equal to the demand. Great difficulty also was found with the insurance companies, which refused to take risks either on the vessels or their cargoes where explosives were carried. Now, though no difficulty is found in placing risks, the rates of ocean insurance are as moderate as on any other merchandise.

“There are a number of railroad companies in the United States that refuse to transport high explosives under any circum-

stances, but upon what grounds they could justify the exclusion of such high explosives from being imported under the regulations of the legislation proposed it would be difficult to imagine. European railway companies have found it to their interest not to pursue so shortsighted a policy, as in case of exclusion the articles are carried surreptitiously concealed with other merchandise, thereby making the danger of premature explosion all the greater. Metal cylinders made to represent oil cans, the cylinders being so constructed with an inner longitudinal partition that a portion amounting to one-tenth of each cylinder was able to and actually did contain oil, while the remaining nine-tenths of the cylinder contained an explosive, was one ingenious method among many others practiced for deceit in transportation. Another almost equally as ingenious was to disguise the high explosive 'tonite' as wine and have it transported as such. In a number of instances parties have been apprehended carrying high explosives on passenger cars in carpetbags or valises and in trunks or chests checked to their destination in baggage cars. In every case the excuse for such wanton recklessness was the prohibition of the railroad company to allow the transportation of such high explosives as freight.

"It was recently asserted as an argument urged for the purpose of obtaining a reduction in the rates of freight asked on explosives, that since the regulations and restrictions by law went into effect in 1875 not a life has been lost by a premature explosion on the railways of Great Britain and Ireland, and the sum of twenty-five dollars (£5) would cover all the damage done to property on such railways up to date. It has been asserted by the railroad companies that they are not responsible for damages in cases of premature explosion if they prohibit the transportation of the explosive, but that they would be liable if transported under regulations of apparent safety but prematurely exploded. After a careful search through the authorities I can find no decision to bear out such an interpretation of the law as existing in this country. This perverted view of the law of damages was used recently in argument in a decision reached by the board of directors by one of our great systems of railroads. Although the officers were all convinced of the safety of the explosive and were willing to transport it, the board of directors decided by an overwhelming vote to continue the suicidal policy of prohibiting the transportation of any and all explosives over their lines.

“As no less than seven kinds of explosives, including detonators, are used in some mines, each being found specially adapted for different work, it can be easily perceived how such action paralyzes the development of that branch of industry in the territory, not including many others, depending for transportation on their system of railroads.”

The report is accompanied by two appendixes. Appendix A contains abstracts of the legislation of Austria, France, Germany, Great Britain and Ireland, Norway and Sweden.

Appendix B is a draft of a proposed “bill to regulate the importation of gunpowder, nitroglycerin and other explosive substances,” and which is as follows:

“Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled: That it shall be unlawful to import into the United States any gunpowder, nitroglycerin, dynamite, gun-cotton, blasting powder, fulminate of mercury, fog signals, fireworks, fuzes, rockets, percussion caps, detonators, cartridges, ammunition of all descriptions and every adaptation or preparation of an explosive to produce effect by explosion or a pyrotechnic effect, except in accordance with the regulations prescribed by this act.

“Sec. 2. For the purpose of this act explosives shall be divided into the following seven classes: Class 1, gunpowder; class 2, nitrate mixture; class 3, nitro-compound; class 4, chlorate mixture; class 5, fulminate; class 6, ammunition; and class 7, fireworks.

“Class 1 includes brown, cocoa, lightning, mammoth, olive, orange, pebble, prism, and all those gunpowders of the ordinary black kind, which are used to discharge cannons, mortars, and muskets.

“Class 2 means any preparation other than gunpowder, ordinarily so called, formed by the mechanical mixture of nitrate with any form of carbon or with any carbonaceous substance not possessed of explosive properties, whether sulphur be or be not added to such preparation, and whether such preparation be or be not mechanically mixed with any other non-explosive substance, and includes amide, cahne, carbazotone, diorexin, perulite, haloxyline, heraklin, johnite, oriental, fortis, grenadine, pudrolithe, pyrolithe, pyrononce, pyronitrite, saxifragine, triumph, safety, xanthine, and all other preparations coming within the above definition.

“Class 3 means any chemical compound possessed of explosive properties, or capable of combining with metals to form an explosive compound, which is produced by the chemical action of nitric acid (whether mixed or not with sulphuric acid), or of a nitrate mixed with sulphuric acid, upon any carbonaceous substance, whether such compound is mechanically mixed with any other substances or not. This class shall have three divisions:

“Division 1 comprises such explosives as colonia, dahmanite, diaspon, dualine, dynamite No. 1, dynamite No. 2, dynamagnite, forcite, fulmi-

natine, gelatine dynamite, gelignite, glonoius, glukodine, glyoxiline, lignose, lithofracteur, matagnite, mataziette, meganite, nitroglycerin, nitrolite, orissite, paleine, petralithe, porifera, rendrock, rhesite, sebastine, scanine, vigorite, virite, westfalite, and any chemical compound or mechanically mixed preparation which consists either wholly or partly of nitroglycerin or some other liquid nitro-compound.

"Division 2 shall comprise such explosives as bellite, carbonite, cellulosa, di-flamyr, emilite, glyceropyroxiline, kinetite, nitromidine, nitasons, nitroline, nitromaanite, petrofracteur, plera, potentite, pyroxiline, roburite, romit, securite, titan, tonite, xyloglodine, xyloidine, and any nitro-compound, except picrates, not comprised in the first division.

"Division 3 will include the explosives known as bronolithe, emmonite, honitite, lithstite, melinite, oxonite, punshon, victorite, and all other chemical compounds in which picric acid is used as a nitro-substitute.

"Class 4 includes such explosives as asphaline, callow, dynamogen, etnite, inline, pyronnome, rock-a-rock, silesite, schneibelite, viel, and any chemical mixture containing a chlorate.

"Class 5 comprises all fulminates used for percussion caps or any other appliances for developing detonation.

"Class 6 includes any explosive used as ammunition when inclosed in any case or contrivance or otherwise adapted or prepared so as to form a cartridge or charge for small arms, cannon, or other weapon, or for blasting, or to form any tube for firing explosives, or to form any safety or other fuse for blasting or for shells, or to form a percussion cap, a detonator, a fog signal, a shell, a torpedo, a war rocket, or other contrivance other than a firework. This class shall have three divisions:

"Division 1 embraces safety cartridges, safety fuzes, for blasting, railroad fog signals and percussion caps.

"Division 2 comprises any ammunition which does not contain its own means of ignition, such as cartridges for small arms, which are not safety cartridges, cartridges for cannon, shells, mines, blasting or other like purposes, shells and torpedoes containing any explosives, fuzes for blasting which are not safety fuzes, fuzes for shells, tubes for firing explosives and war rockets.

"Division 3 will comprise any ammunition which contains its own means of ignition and is not included in Division 1, such as detonators, cartridges which are not safety cartridges, fuzes for blasting which are not safety fuzes, fuzes for shells, and tubes for firing explosives.

"Class 7 will include all fireworks, and is divided into two divisions:

"Division 1 comprises any firework composition containing any chemical compound which is used for the purpose of making fireworks, and is not included in the former classes of explosives.

"Division 2 includes all manufactured fireworks such as squibs, crackers, serpents, rockets (other than a war rocket), maroon, star, wheel, chinese fire, roman candle, or other article adapted for the production of pyrotechnic effects or signals.

"Sec. 3. No explosive shall be imported into the United States except by virtue of an importation license granted by the Secretary of the

Treasury, and the unloading and delivery, or the transshipping of any explosive shall be included within the provisions of this section.

“Sec. 4. The Secretary of the Treasury may grant an importation license for any such explosive, and may annex thereto any prohibitions and restrictions with respect to the composition and quality of the explosive and the unloading, landing, delivery, and conveyance thereof and such further restrictions as he may think fit for the protection of life and property.

“Sec. 5. The license shall be of such duration as the Secretary of the Treasury may fix, not to exceed six calendar months, and shall be available only for the person or persons named in the license. It shall contain the provision that it may be revoked by the Secretary of the Treasury at any time.

“Sec. 6. The owner and driver of any vehicle, the owner or master of any ship or boat, and the railroad company or conductor of any railroad car on which any explosive is imported into the United States shall not permit the same to be unloaded and delivered to any person who does not hold a license to import the same from the Secretary of the Treasury.

“Sec. 7. No vehicle or wagon on which explosives are imported into the United States shall contain more than 4000 pounds, including weight of enveloping package, and shall not be transported at a faster gait than a walk. It shall carry a black flag, in dimension at least 3 feet square, displayed so as to be of easy view. An extra man to the driver shall accompany such vehicle or wagon, whose duty it shall be to keep off and warn all persons who are smoking from approaching such vehicle or wagon. If moving in trains, each vehicle in such wagon train shall preserve an interval of at least 75 feet from the preceding vehicle.

“Sec. 8. All ships or boats conveying explosives to be imported into the United States shall carry flags of at least 3 feet square, to be displayed at masthead in the former and at the stern in the latter, black in color when on those plying in fresh water and red for all sea-going vessels, and no ship or boat shall carry more than 50,000 pounds weight of explosives.

“Sec. 9. No railroad car on which explosives are imported into the United States shall carry more than 10,000 pounds, including weight of enveloping package, and the number shall be limited to five, allowed to be attached to any freight train. There shall be at least three empty cars, or cars filled with non-combustible merchandise, preceding or following any such cars loaded with explosives. No explosives shall be imported into the United States on any gondola or open car.

“Sec. 10. In the event of any breach by any act of default of the provisions of the preceding sections, with respect to the importation of an explosive, or of the provisions of any importation license, all or any part of the explosive with respect to which such breach is committed, or being in any vehicle, wagon, ship, boat, or railroad car in connection with which such breach is committed, may be forfeited.

“Sec. 11. The gunpowder of class 1, if to be imported into the United States for private use and not for sale, and in safety cartridges, to the amount of 5 pounds for each passenger, shall not be subject to the restriction imposed by this act.

“If imported for sale and not exceeding 5 pounds, it shall be contained in a substantial case, bag, canister, or other receptacle, made and closed so as to prevent the gunpowder from escaping. If exceeding 5 pounds in amount, it shall be contained either in a single package or a double package. A single package shall be a box, barrel, or case of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure while being conveyed, and will not allow the gunpowder to escape. If it is packed in a double package, the inner package shall be a substantial case, bag, canister, or other receptacle made and closed so as to prevent the gunpowder from escaping, and the outer package shall be a box, barrel, or case of wood or metal, or other solid material, and shall be of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow the gunpowder to escape. The interior of every package shall be, whether single or double, free from grit and otherwise clean, and every such package, when actually used for the package of gunpowder, shall not be used for any other purpose. There shall not be any iron or steel in the construction of any such package, unless the same is effectually covered with tin, zinc, or other material. The amount of such gunpowder in any single package, or, if there is a double package, in any one outer package, shall not exceed 100 pounds, and on the outermost package there shall be affixed the word “Gunpowder” in conspicuous characters by means of a brand or securely attached label or other mark.

“Sec. 12. The explosives of class 2 (nitrate mixture) if not exceeding 5 pounds in amount shall be contained in a substantial case, bag, canister, or other receptacle made and closed so as to prevent any explosive from escaping. If exceeding 5 pounds in amount, it shall be contained in a double package, the inner package being a substantial case, bag, canister, or other receptacle, made and closed so as to prevent any explosive from escaping, and the outer package shall be a box, barrel, or case of wood or metal, or other solid material, and shall be of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape; and the amount of explosive in any one outer package shall not exceed 100 pounds. The interior of every one such package shall be free from grit and otherwise clean, and every package when actually used for the packing of one nitrate mixture shall not be used for the packing of any other nitrate mixture or for any other purpose. There shall not be any iron or steel in the construction of any package unless the same is effectually covered with tin, zinc, or other material, and on the outermost package there shall be affixed in conspicuous characters, by means of a

brand or securely attached label or other mark, the word "Explosive," with the name of the explosive, followed by the word "Nitrate mixture," and the name and address of the sender.

"Sec. 13. The explosives of class 3 (nitro compounds), if not exceeding 5 pounds in amount, shall be contained in a substantial case, bag, canister, or other receptacle made and closed so as to prevent any explosive from escaping. An explosive of the division 1 of this class, if exceeding 5 pounds in amount, shall be contained in a double package, the inner package being a substantial case, bag, or covering without any metal in the construction thereof, and so made and closed as to prevent any explosive from escaping; and any one of such packages shall not contain more than 10 pounds, and the outer package shall be a box, barrel, or case of wood or other solid material (other than metal), and shall be of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape. The inner or outer package or both shall be thoroughly waterproof, and the amount of explosive in any one outer package shall not exceed 50 pounds. An explosive of division 2 of this class, if exceeding 5 pounds in amount, shall be contained in a double package. The inner package being a substantial case, bag, canister, or other receptacle made and closed so as to prevent any explosive from escaping; and the outer package shall be a box, barrel, or case of wood or metal, or other solid material, and shall be of such strength, construction, and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape; and the amount of explosive in any one outer package shall not exceed 50 pounds.

"An explosive of division 3, if exceeding 5 pounds, shall be contained in a double package, the inner package being a substantial case, bag, canister, or other receptacle made and closed so as to prevent such explosive from escaping; and the outer package shall be a box, barrel, or case of wood or metal or other solid material, and shall be of such strength, construction and character that it shall not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape; and the amount of explosive in any one outer package shall not exceed 100 pounds. Whatever be the amount of the explosive and to whatever division it belong, the interior of every package shall be free from grit and otherwise clean, and every package when actually used for the packing of one nitro compound shall not be used for the packing of any other nitro compound or for any other purpose, and there shall be no iron or steel in the construction of any inner or outer package unless the same is effectually covered with tin, zinc, or other material. On the outermost package there shall be affixed in conspicuous characters, by means of a brand or securely attached label, or other mark, the word "Explosive," with the name of the explosive followed by the words "Nitro compound," "Division " "1," "2," or "3," as the case may be, and the name and address of the sender.

" Sec. 14. Explosives of class 4 (chlorate mixture), if not exceeding 5 pounds in amount, shall be contained in a substantial bag, case, canister, or other receptacle made and closed so as to prevent any explosive from escaping. If exceeding 5 pounds it shall be contained in a double package. The inner package shall be a substantial case, bag, or covering without any metal in the construction thereof, and so made and closed as to prevent any explosive from escaping, and any one of such packages shall not contain more than 10 pounds; and the outer package shall be a box, barrel, or a case of wood or other solid material (other than metal), and shall be of such strength, construction and character that it will not be broken or accidentally opened, or become defective, or insecure whilst being conveyed and will not allow any explosive to escape, and the amount of explosive in any one outer package shall not exceed 50 pounds. In addition, in the case of an explosive of division 1 of this class, the inner or outer package or both shall be thoroughly waterproof. The interior of every package shall be free from grit and otherwise clean, and every package when actually used for the packing of one chlorate mixture shall not be used for the packing of any other chlorate mixture, or for any other purpose, and there shall not be any iron or steel used in the construction of any outer package unless the same is effectually covered with tin, zinc, or other material. On the outermost package there shall be affixed in conspicuous characters by means of a brand, or securely attached label, or other mark, the word "Explosive," with the name of the explosive followed by the words "Chlorate mixture compound, division 1" (or 2, as the case may be), and the name and address of the sender.

" Sec. 15. Explosives of class 5 (fulminates) which are of such character that they cannot be packed mixed with water, or that danger would arise from such mode of packing, shall be packed in such manner as shall be specially directed by the Secretary of the Treasury. Any other explosive of this class shall be packed in bags or coverings of calico, canvas, or other material permeable to water, and containing each not more than 25 pounds, and so made and closed as to prevent any explosive from escaping. Such bags or coverings shall be packed in a case containing sufficient water to insure the explosive being kept constantly wet, and such inner case shall be packed in an outer case containing sufficient water constantly to surround the inner case, and both cases shall be of such strength, construction and character that neither will be broken nor accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any fulminate or water to escape, and the amount of explosive in any outer case shall not exceed 200 pounds. Every package when actually used for the packing of one fulminate shall not be used for the packing of any other fulminate or for any other purposes, and on the outer case there shall be affixed in conspicuous characters, by means of a brand or securely attached label, or other mark, the word "Explosive," with the name of the explosive followed by the words "Fulminate, division 1" (or 2, as the case may be), and the name and address of the sender.

“Sec. 16. Any explosive of divisions 1 and 2 of class 6 (ammunition) shall be contained in a box, barrel, or case of wood, metal, or other solid material, and of such strength, construction and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape, and any one such package shall not contain more than 100 pounds of such ammunition. Any explosive of division 3 of this class shall be packed in a double package. The inner package shall be a substantial case, bag, canister, or other covering made and closed so as to prevent any explosive from escaping, and shall not contain more than 2 pounds of such explosive. The outer package shall be a box, barrel, or case of wood, metal, or other solid material, and shall be of such strength, construction and character that it will not be broken or accidentally opened or become defective or insecure whilst being conveyed, and will not allow any explosive to escape, and any one such outer package shall not contain more than 50 pounds. The interior of every package, whether single or double, shall be free from grit and otherwise clean.

“Every package, whether single or double, when actually used for the packing of one description of ammunition shall not be used for the packing of any other description of ammunition, or for any purpose, provided that with explosives of division 1 of this class there may be packed any article which is not of an inflammable or explosive character, or liable to cause fire or explosion. On the outermost package there shall be affixed in conspicuous characters, by means of a brand or securely attached label or other mark, in the case of percussion caps or safety fuzes for blasting, the words “percussion caps,” or “safety fuzes for blasting,” as the case may be, with the name and address of the sender, and in the case of any other ammunition the word “explosive,” with the name of the explosive, followed by the words, “ammunition, division 1” (or 2 or 3, as the case may be), and the name of the sender; also indicate if cartridges and charges for cannon, shells, mines, blasting, or other like purpose; the name of the explosive material contained in such cartridge or charge shall be given as “explosive blasting cartridge containing dynamite ammunition, division 2.”

“Sec. 17. An explosive of division 1 of class 7 (fireworks) shall be contained in a double package. The inner package shall be a substantial canister case, or other receptacle, hermetically closed, and contain no more than 1 pound of explosive, and the outer package shall be a box, barrel, or case of wood, metal, or other solid material, and shall be of such strength, construction and character that it will not be broken or accidentally opened, or become defective or insecure whilst being conveyed, and will not allow any explosive to escape; and any outer package shall not contain more than 20 pounds, and there shall not be any iron or steel used in the construction of any such inner or outer package unless the same is effectually covered with tin, zinc, or other material. An explosive of division 2 of this class exceeding 5 pounds

in weight shall be contained in a box, barrel, or case of wood, metal, or other solid material, and of such strength, construction and character that it will not be broken or accidentally opened, or become defective and insecure whilst being conveyed, and will not allow any explosive to escape, and the amount of explosive in any one package shall not exceed 100 pounds. The interior of every package, whether single or double, shall be free from grit and otherwise clean, and when such package shall be used for the packing of fireworks shall not be used for any other purpose, and on the outermost package there shall be affixed, in conspicuous characters, by means of a brand or securely attached label, or other mark, the word "Explosive," and the name of the explosive followed by the words "Fireworks, division 1" (or 2, as the case may be), and the name and address of the sender.

"Sec. 18. The Secretary of the Treasury shall have the power to increase the amount of the maximum weight of any explosive allowed to be contained in any one package imported into the United States as prescribed by the act, such increase of weight to be specified in the body of the importation license granted and to be limited to one shipment and during the period of six months ensuing from the date of such license.

"Sec. 19. All officers of the customs shall have the same power with respect to any explosive imported, and the vehicle, car, ship, or boat containing the same, as they have for the time being with respect to any article on the importation of which restrictions are for the time being imposed by the statutes of the United States relating to such importation, and the vehicle, car, boat, or ship containing the same, and the statutes for the time being in force relating to such importation for any such article, or any vehicle, car, ship, or boat shall apply accordingly.

"Sec. 20. The importation from any foreign country into the United States on any railway car of nitroglycerin, or any fulminate, except the fulminate of mercury, is prohibited, and any person who knowingly ships or attempts to ship the same on any such railway car, for such purpose, shall be deemed guilty of a misdemeanor and punished by fine not exceeding \$2000, or imprisonment not exceeding eighteen months, and the articles to be liable to seizure and forfeiture.

"Sec. 21. Every person who forges or counterfeits any license granted or required in pursuance or for the purpose of this act, or willfully makes use of any such forged, counterfeit, or false license, shall be liable to imprisonment for a term not exceeding two years.

"Sec. 22. Nothing in this act shall render liable to any penalty or forfeiture the owner or master of any ship or boat or carrier, or the person having charge of any carriage, for any act done in behalf of this act, if he proves that by reason of stress of weather, inevitable accident, or other emergency, the doing of such act was, under the circumstances, necessary and proper.

"Sec. 23. In the event of any breach by any act or default of the provisions with respect to the importation of an explosive, or of the pro-

visions of any importation license, the owner or master of such ship or boat, and the licensee or person to whom the license is delivered shall each be liable to a penalty not exceeding \$500, and to a further penalty not exceeding 50 cents for every pound of such explosive.

“Sec. 24. Where a carrier or owner or master of a ship or boat, on which an explosive is imported from any foreign country into the United States, is prevented from complying with the provisions contained in the preceding sections, by the willful act, neglect, or default of the consignor or consignee of the explosive, or other person, or by the improper refusal of the consignee or other person to accept delivery of the explosive, such consignor, consignee, or other person who is guilty of such willful act, neglect, default, or refusal shall be liable to the same penalty to which the carrier, owner, or master is liable for such breach, and his conviction shall exempt the carrier, owner, or master from any penalty or forfeiture whatsoever.

“Sec. 25. Where a court before whom a person is convicted of any offense in breach of the regulations set forth in the preceding sections has power to forfeit any explosive imported from any foreign country into the United States, owned by or found in the possession or under the control of such person, the court may, if it think it just and expedient, in lieu of forfeiting such explosive, impose upon such person, in addition to any other penalty or punishment, a penalty not exceeding such sum as appears to the court to be the value of the explosive so liable to be forfeited.

“Sec. 26. That all laws or parts of laws inconsistent with any of the provisions of this act be, and the same are hereby, repealed.”

This recommendation has been embodied in H. R. 8483, of the 53d Congress, third session, introduced by Mr. Wheeler of Alabama.

“Operations of the Division of Military Engineering of the International Congress at Chicago,” *Ex. Doc. No. 119*, 53d Congress, second session, 1894, which is a stout volume of about 1000 pages, liberally illustrated, contains an article entitled “Explosives” by W. R. Quinan (pages 429-441), which is an excellent, though too brief, a review of the progress in the explosive art in the United States during the past thirty years, both from the industrial and military standpoint. It will be very wise for those using Guttman’s book, reviewed below, to supplement it with Quinan’s article if they wish to know how widely the American departs from the European practice.

Under the title “The Development of Explosives during the Last Quarter Century” (pages 451-457), Lieutenant Willoughby Walke gives “a brief resumé of the recent development of explo-

sives and the underlying principles upon which their manufacture is based," which, while entertaining, contains nothing new either in statement or treatment.

Under the title "The Applications of Explosive Substances," *The Polytechnic*, **10**, 125-133; 1894, publishes an address delivered by Prof. Charles E. Munroe before the Rensselaer Polytechnic Institute of Troy, N. Y., in which the manifold uses of these bodies in the arts and industries, as well as in war, are set forth and described in a popular manner.

Dr. Edwin Pynchon, under the title "High Explosives as a Means of Propulsion in Aerial Navigation," describes in *Transportation*, **3**, 17-21; 1894, with the aid of a considerable number of cuts, a novel air-ship which he has invented and which depends on the explosion of dynamite for its source of energy.

Speaking of this feature of his invention, he says: "The most important part of the whole device is the mechanism for using high explosives. From the magazine room, which is well forward, there extend rearwards two solid oval or grooved pipes of about one inch calibre, each terminating by passing through the upper edge of a concave detonating plate, preferably made of some copper alloy, which plates are placed one at either side of the stern of the vessel, exterior thereto and near the horizontal center of the ship's weight. Properly prepared cartridges are to be automatically fed to these pipes at suitable intervals by a mechanism similar to that of a magazine gun. The cartridges when delivered into the pipes are to be shot by pneumatic pressure to the outer opening at the rear of the vessel and then exploded in the concavity of the detonating plates by aid of the electric current. It will probably be found that the best results will be attained by having the explosion take place near the center of the detonating plate and but a few inches therefrom. The maximum push will thus be secured by the slight air cushion thus provided.

"In order to secure the natural expansive or explosive effects of dynamite, it has heretofore been detonated by the use of a blasting cap, which is first exploded by electricity, or a fuze, and which, by its explosion, generates both the intense heat and concussion required for the detonation of the high explosive. Considerable heat, or the spark of the electric current, when applied to loose

dynamite, which is exposed in the open air, will cause it to ignite and burn, though it is not thus exploded, but 'if, when ignited, it be enclosed in a hermetically sealed vessel with resisting walls, it explodes under the influence of heating' (Berthelot). This is owing to the increase in temperature produced by the retention of the first gases of combustion. Dynamite is also exploded when suddenly heated to a sufficiently high temperature, which is found to be about 420° F. From the above data it is easy to see how dynamite or nitrogelatin may be perfectly exploded without the use of the dangerous fulminate blasting cap. The only requirements would be to first have the explosive encased in a suitable and strong shell or container, and second, to have passing through such cartridge, and imbedded in the explosive, a few strands of fine iron wire which would be heated to a point of incandescence by an electric current of sufficient voltage, say 20 v.

"In using such air-ship, after some degree of ascent and forward motion has been made by use of propeller wheels, a pair of cartridges of low power are caused to detonate. These cartridges are to be fed to their respective tubes, and by a moderate force of compressed air slowly shot through the same. When both cartridges are in proper position for firing a weak electric current is closed, which thereby automatically throws a switch and allows passage through the cartridges of a sufficiently strong current of electricity to fire the same. At the start, when the speed of the ship is moderate, light charges should be used, and said charges increased gradually in size or strength until the maximum speed of the vessel is attained, which may then be maintained by using the maximum charge with such frequency as practice teaches to be best, and which would be more frequent when adverse winds are being encountered than when going with a favorable breeze. As in my suggested plan the propelling power is changed from the forward end of the ship to its stern whenever change is made from use of propeller wheels to use of explosive accelerator, and as it is known that the center of weight should not be far from the center of power, it will probably be found desirable to provide for a certain per cent. of freight or fuel ballast being moved from the middle of the ship toward its stern when such change of powder is being made. In fact, movable ballast will undoubtedly be found of great utility in balancing the ship at all times, no matter what style of propeller is being used.

“In aerial travel the great desideratum is ceaseless and rapid onward motion, and at an altitude of from 500 to 2000 feet the best results should be attained. It is quite probable that a speed of 150 to 200 miles an hour can be easily had, and will, in fact, be necessary in order to insure a commercial success. I have estimated, that with a ship of the size mentioned, after a full speed of 200 miles an hour has been attained it can be maintained by the explosion, every five seconds, of a pair of 60 per cent. nitrogelatin cartridges, each weighing two ounces. There will thus be required about one hundred pounds of the explosive for each hundred miles of the journey, and the cost, including a very liberal allowance for construction and insulation of the cartridges, should not exceed forty cents per pound. The expense would then be \$1.20 per minute, or \$72 per hour, being less than forty cents per mile traveled. Three thousand pounds of fuel would thus more than provide for a trans-Atlantic voyage, and the cost thereof should not exceed \$1000, which would be inexpensive for a vessel of its probable carrying capacity, which, in addition to fuel and supplies, should easily transport twenty-five adults, consisting of a crew of ten and fifteen passengers. Let man but partially succeed in the field of aerial navigation and there is no doubt but that the maximum of success will follow in much less time than has been required in the evolution of the ocean steamer.”

Ex. Doc. No: 20 of the U. S. Senate, 53d Congress, first session, comprises the report of the U. S. Commission on Safe and Vault Construction, which is issued as a volume of 90 pages, illustrated by upwards of 100 cuts and plates. The appendix records the results of the experiments made by Professor Charles E. Munroe and Lieutenant Rodman in attacking safes and vaults by means of nitroglycerin, dynamite, gun-cotton and other explosives.

The experiments were made to demonstrate the relative efficiency of the various systems of construction tested in resisting either “burglarious operations” or “mob violence,” it being understood by a “burglarious operation” that the contents of a closed and locked safe should be made accessible within twenty-four hours by the use of materials such as a party of men could smuggle into a bank and which could be used without attracting attention or doing material damage to the surroundings; and by “mob violence,” that the vaults are supposed to be in the pos-

session of a mob which has ample time and quantities of explosives at hand, and is indifferent to the noise that is made or the destruction that is wrought, provided the treasure be secured.

Among the many accounts of burglarious operations is one in which a \$3000 square laminated safe of the most approved construction was attacked by inserting in the crevice about the locked door 4.8 ounces of nitroglycerin, and in eight minutes after the operation of loading was begun the charge was fired, with the result that the whole of the joint below the door was blown out and a hole made of sufficient size to admit the hand and arm, while the doors and divisions of the interior compartments were completely shattered. On repeating the operation with 4.5 ounces of dynamite the door was torn completely off.

Among experiments made to demonstrate the resistance of structures to attack by a mob was one upon a safe 29 inches cube, with walls 4.75 inches thick, made up of plates of iron and steel. Two charges of untamped dynamite were fired upon the safe. The first charge of 9.5 pounds in weight made a hole three inches in diameter clear through to the interior of the safe, while a second charge of 12.5 pounds enlarged this hole to 5.5 inches.

These dynamite charges were built up in a peculiar way, invented by Professor Munroe. He has stated in these Notes* that he found that when he perforated disks of compressed gun-cotton and detonated these disks in contact with metal, the metal plates could be perforated, though solid blocks of gun-cotton of greater weight failed to effect the perforation of similar plates, and he advanced a theory to account for this action. Acting on this theory when making the experiments before the Safe and Vault Commission, he took a metal can about eight inches in height and of suitable diameter, placed its open mouth downward and bound around it sticks of dynamite so placed that they touched sides; then a solid bundle of sticks was placed on the base of the can and the detonator placed in this. When this hollow cartridge was fired with the open or hollow end "in contact," it was found that plates of metal could be pierced with readiness which would successfully resist attacks by solid charges of the same explosive of many times the weight.

It is believed that this "hollow high explosive cartridge" will eventually find application in warfare, and that by employing it

* Proc. Nav. Inst., 13, 594; 1887, 14, 771; 1888.

in place of the present expensive methods of testing armor plates in vogue at proving grounds there will follow a gain in speed and reduction in expense without any loss in accuracy or reliability.

Mr. Walter D. Field gives in the *J. Am. Chem. Soc.* **15**, 140-144; 1893, **16**, 487-498, 543-549; 1894, an illustrated account of "Pyroxylin, its History and Manufacture," in which he has collated from the patent literature and elsewhere, memoranda regarding the development of this important industry, and illustrations of the various apparatus employed or proposed.

By the term pyroxylin is understood the soluble nitric ethers of cellulose, namely, the di-, tri-, tetra- and penta-nitrates. From the date of the use of pyroxylin in photography, as collodion, by Scott Archer in 1851, the number of its uses has increased until, at the present time, tons of the lower nitrates of cellulose are produced yearly. In the form of celluloid it finds manifold applications. As a varnish it is used on penholders, pencils, silver and brass ware. Articles are bronzed with it as a medium, and an artificial leather has been produced by its aid which has already found a ready market to the extent of many thousands yards.

The portion of the article which is likely to prove of most interest to the student of explosives is that which is devoted to the variation in the composition of the pyroxylin produced with the differences in the strength and proportions of the acids, the time and temperature of exposure, and the relative humidity during nitration, and also that dealing with the behavior of the product toward solvents.

Dr. J. E. Blomène treats of "The Manufacture of Soluble Nitrocellulose for Nitrogelatin and Plastic Dynamites" in *J. Am. Chem. Soc.* **17**, 411-419; 1895, where, after describing what sort of material is required and giving the method of preparing the cotton, he says:

"As is always the case, where a number of nitro-derivatives can be obtained simply by using a stronger or weaker nitric acid and by changing the conditions under which it is used, the tri-nitro-cellulose can be obtained in several different ways. The factors to be taken into consideration are:

(1) The *proportion* of sulphuric and nitric acids used in the mixture.

(2) The *strength* of the two acids respectively.

(3) The *length of time* the acid mixture is allowed to be in contact with the cotton.

(4) The *temperature* maintained during the reaction.

(5) The *construction* of the plant itself; and a number of minor conditions, such as the humidity of the atmosphere at the time of the reaction.

I will simply indicate the importance of each one of these conditions and then describe *one* way, which I have found, after numberless experiments, to give satisfaction; that is, to produce a nitrocellulose soluble in nitroglycerol at a reasonable cost.

If too *much* sulphuric acid be used this is likely to attack the cotton *before* the nitric acid begins to act, converting it partly into cellulose hydrate (this will later be converted into a higher nitration degree by the nitric acid, as it is much more readily acted upon than the cellulose and will then form an insoluble nitrocellulose) and partly into glucose, which will again partly be nitrated to nitrosaccharose, which is insoluble in nitroglycerol and, besides, a very dangerous substance to have present. Again, if too *little* sulphuric acid be present it will soon form its highest hydroxide and be unable to absorb more of the water rapidly formed during the reaction, when the nitric acid will become diluted and be unable to nitrate the cellulose. The right proportion of acid mixture is, therefore, of great importance.

If *too strong* sulphuric acid be used the result will be the same as above-mentioned for an excess of it; if too strong or too weak nitric acid be used it is obvious that a higher or lower nitration degree than the one desired will result. It goes without saying, therefore, that the strength of the acids is of utmost importance.

In the reaction between nitric acid and cellulose no fumes are given off, except what is driven off by the heat (in which it widely differs from several other nitration processes), and although the reaction becomes feebler and, eventually, completely stops, when the acid has been diluted to a certain limit it only gradually diminishes in force, and therefore the time has to be so balanced that the lower nitration degrees have been passed without part of the cellulose having been too highly nitrated when it is stopped. Hence the importance of careful regulation of the time.

If the nitration pots are surrounded with water kept at a constant temperature, it will be found that the quickness and degree of the nitration depend, to a considerable extent, upon the temperature of this water. Thus, if the temperature be kept up to a high degree the nitration will be much more rapid, but at the same time experience has shown me that, in this way, a *mixture* of different nitration degrees is much more apt to result than the uniform nitration from one degree to another. Curiously enough, the same result is obtained if no external heat at all be applied, and accordingly in my experience a carefully maintained temperature of 70° C. has been found to give the most uniform result; but no doubt good, and perhaps more economical results can be reached by elevating the temperature of the surrounding water.

It is within the experience of every chemical manufacturer how much the size and construction of the vessels in which the reaction takes place influence the result, and this is fully as true in this industry as in any other. It is especially so as the cotton is so bulky that it is hard to keep every part of it in contact with the acid mixture. Under otherwise the same conditions I have found quite a difference in the product whether it was made on a clear and dry day, or when the day was rainy or cloudy, the more so as the building in which the operation takes place has to be left open to a great extent to allow the acid vapors to be carried away.

Even in very large dynamite works it is not always practicable to adopt the very best appliances for the manufacture of nitrocellulose, because it must necessarily be only a small part of the plant (an average of two per cent. of the ingredients), and can only be conducted by dependence for labor, material, etc., on other parts of the works. In a large plant for the exclusive manufacture of this kind of nitrocellulose the conditions would be more favorable for improvements.

The acid mixture I have found best to use is the following: Nitric acid of 1.430 sp. gr., free from chlorine and such an amount of sulphuric acid as would influence the specific gravity, forty parts; and sixty parts of sulphuric acid of 1.835 sp. gr. The specifications for acids governing the supply for other parts of the works can be adopted for this. It is self-evident that this proportion of acids is only necessary when the work is carried on as hereinafter described, and can be greatly varied under different

conditions. Such an acid mixture as this cannot be stored in iron drums for any length of time and is therefore troublesome to get, if the nitric acid is not manufactured at the works. The nitric acid must be shipped in carboys; the sulphuric acid can be shipped in drums.

In mixing the two acids a sufficient quantity can be mixed at one time to last for two or three days' supply, and then stored in drums, as the acid will hardly, in this short time, affect the iron to any great extent. The mixing is best effected in a wooden tub lined with heavy lead in such a way as to allow a water-jacket of about two inches around it. (A condemned nitroglycerol apparatus with the coils removed answers this purpose very well.) If compressed air be at hand this should be used as a stirrer by placing a small perforated lead coil at the bottom of the tank and letting the air bubble through the mass, since it is very difficult to get any other kind of stirrer that will stand the acids. The men should be warned to have the earthenware faucet at the bottom of the tank well greased, to tap it very gently, to always use their rubber gloves, and to have an ample supply of water close at hand.

This mixture, although carefully made from acids of 1.430 and 1.835 sp. gr. respectively, will vary in specific gravity from 1.678 to 1.682, but if below or above this, some mistake has been made in the mixing or stirring. The nitric acid should always be dumped in the tank first and the sulphuric acid afterwards, so as to give the latter a chance to mix by gravity as much as possible. Just before using, the acid mixture should be stirred again. For this purpose it is convenient to have a lead-lined tank, with an air-stirrer, of a size to hold one charge for the nitrating pots in use, in which the mixture is stirred up thoroughly and then drawn off for each pot as rapidly as possible.

The arrangement of the nitration pots, of course, must depend on existing conditions, such as size and form of the building, the size of the pots, the material used for confining the water around them, the supply of water of suitable temperature, etc. Under ordinary circumstances I have found it practicable to use earthenware pots sixteen inches deep and thirteen inches in diameter, enclosed in wooden troughs twenty feet long by twenty inches wide, connected by means of leaden pipes. If shorter it is a waste of lumber, if longer they are likely to leak from the pres-

sure. If the troughs can conveniently be made from concrete or brickwork with water-tight mortar, of course they can be extended to any desired length.

Experience has shown two pounds to be the right amount of cotton to be used in one nitration pot. To save time and labor it is important to nitrate as much as possible at one time, but the necessity of getting a uniform product limits the amount; and as the cotton clogs or packs together as soon as wet by the acid mixture, only so much can be used at one time as will allow the mixture to act uniformly on the whole bulk of the cotton, without nitrating the outer portion too much and the inner portion too little. After having tried different amounts I have reached the conclusion that (under the given conditions) two pounds is the maximum that can safely be treated in one nitration pot.

Forty-five pounds of well-stirred acid mixture is weighed out and placed in the pots, which are surrounded by water heated to 70° C. The two pounds of cotton for each pot should be previously weighed out, and ready to be put in so as to have this done as nearly simultaneously as possible. It is now immersed in the acid mixture, turned about a few times with a fork and kept down by a perforated cover. The only reason for using such an excess of acids is that the cotton must be covered by it; if good covers are used, forty pounds or less is enough. Besides the perforated covers, each pot should be provided with solid overlapping covers to keep back the fumes. It is now left for one hour and ten minutes, except that after thirty-five minutes the cotton is quickly turned about with the fork a couple of times and the covers replaced. After this the nitrated cotton is quickly taken up, squeezed with the fork and wrung out in a centrifugal machine. From this it is taken to a large-sized tank well filled with cold water, where it is thoroughly washed. It should be kept in this tank in running water for about one hour. It is well to have a large quantity of water to prevent heating by adherent sulphuric acid, but it is not so important as in the case of gun-cotton, because it is not so easily ignited by the heat generated, nor is the acid as strong as in the latter case. It is then transferred to another tank of the same size. This is conveniently placed below and the nitrocellulose transferred on a wooden slide. Here it is washed in a sal-soda solution. From

this it is taken to a pulping machine or hollender, where it is reduced to a fine pulp. This part of the process is of the greatest importance, as it has been proven time and time again that if insufficiently pulped it is hard, if not impossible, to dissolve it in nitroglycerol. I have found that nitrocellulose which had before been rejected as insoluble, worked very well after it had passed two or more hours in the pulp machine. From the pulp machine it is emptied into a large tank, allowed to settle, and the water filtered off. It is then passed either through a centrifugal machine or a hydraulic press, and thus freed from water as far as possible. It is spread in drying boxes to a depth of about two inches and kept at a temperature of about 80° C. till thoroughly dried. After that it is rubbed through fine screens until as fine as the finest flour. If treated in this way the nitrocellulose will dissolve very quickly in nitroglycerol. Seven per cent. of nitrocellulose dissolves in ninety-three per cent. nitroglycerol in less than twenty minutes to a transparent jelly, and three and five-tenths per cent. gives the nitroglycerol the consistency of syrup. Several hundred analyses of nitrocellulose prepared in this way show it to contain from 20.5 to 21.8 per cent. of NO_3 , which very nearly corresponds to the formula of trinitrocellulose. The process carried out in this way is simple and requires no great skill or experience. The cost under ordinary circumstances and with conscientious supervision varies between thirty-five to forty cents a pound. The spent acid must, of course, be taken care of either by regaining it or by using it direct for other chemical processes."

Under the title of "The Manufacture of Smokeless Powder," Oscar Guttman gives in the *J. Soc. Chem. Ind.* **13**, 575-584; 1894, a description of the methods employed, with illustrations of the apparatus used, generalizing his methods as one is compelled to when so many competitors are in the field and all the processes are so new. The description is preceded by a historical resumé of these powders, and succeeded by a general statement as to their properties and advantages, together with a profitable discussion such as characterizes the meetings of British scientific societies. The author does not often indulge in criticism, but he seems to have fallen into error in his remarks on the formation of indurite. Altogether, the paper is a valuable one, as the former articles by this author have been, and it is worth reading in full, and critically.

English Patent No. 6129, April 9, 1891, has been granted the Dynamite Actiengesellschaft Nobel of Vienna, for "Improvements in the Manufacture or Production of Gunpowder or like Explosives," the object of the invention being the manufacture of a smokeless powder from nitrocellulose without having added substances which dissolve or gelatinize the nitrocellulose.

For this purpose nitrocellulose in a state of fine meal is mixed with di- or tri-nitro derivatives of benzene, toluene, xylene or naphthalene, the proportions of nitrocellulose to the nitro derivatives depending on the projective force required, varying from 99 to 70 parts by weight of the former to 1 to 30 parts by weight of the latter.

The Boston *Herald* of September 6, 1894, announces that one of "the largest blasts of dynamite that has ever taken place in a quarry occurred at 5 o'clock last evening at the Palisades quarries, about a mile and a half from Fort Lee, New York.

Two shafts were sunk in the face of the palisades, about 65 feet in depth, and into each shaft fully 1500 pounds of dynamite were placed.

When everything was in readiness, the connections were made and the mountain was shorn of about 1200 feet of surface. This displacement extended about 500 feet, on an average, into the rock. The weight of the rock displaced is estimated at 80,000 tons.

The shock was felt at Fort Washington, directly across the river, owing to the stratum of rock which extends to that point."

Among other large blasts we may note that occurring at this same Fort Lee quarry in 1893, in which 4000 lbs. of dynamite were fired and 100,000 tons of rock removed, and the one occurring the same year at the Dinorwic quarries, Llanberis, when $2\frac{1}{2}$ tons of gelatine dynamite were used in the charge and 180,000 tons of rock were displaced.—*Ann. Rept. H. M. Insp. Exp.* for 1893, p. 74.

The New York *World*, February 3, 1892, reports an explosion of alcohol vapor which occurred at Rummel Company's hat factory, Newark, N. J., on February 2, and through which three men were killed and two wounded, while the building, a large two-story one, which had been recently erected, was unroofed, its side walls were shattered, and the glass in the windows of this

and the surrounding buildings for a considerable distance about was destroyed. The description of what occurred is very vague, but it appears that a new machine called an alcohol condenser had recently been erected in the factory; that on the day of the accident it was out of order, and that, at the time of the explosion, a plumber was at work repairing it. As 158 men and women were at work in the building at the time of the explosion, it is remarkable that the casualties were so light.

On the evening of March 9, 1893, a startling explosion occurred in the freight station of the Midland Railway at Whitecross Street, London, which, being seemingly due to a mysterious agency, gave rise to considerable anxiety and led to an investigation the following day by Col. Majendie, H. M. Chief Inspector of Explosives, and Dr. A. Dupré, Chemist to the Home Office.

The results of this investigation are given by the latter in *J. Soc. Chem. Ind.* **13**, 198-200; 1894, under the title of "Note of an Interesting Explosion caused by Sodium Peroxide," in which it is shown that when this powerful oxidizing agent, which is now being manufactured on an extended scale, is mixed with wood meal, shavings, hay, cotton, wool, sulphur, bisulphite of sodium or other combustible bodies, the mixture is set on fire or exploded by simply moistening with water. In fact, a slightly rough deal board may be set on fire by merely covering it with a layer of peroxide and dropping water on it. When once the combustible has taken fire a very fierce combustion results so long as any peroxide is left, the effect being greatly enhanced by the melting of the peroxide, which, wherever it flows, sets fire to everything combustible. Hence sodium peroxide differs from most oxidizing substances in the fact that its power is developed by either fire or water.

These properties of the peroxide present a fresh danger to carriers. In the accident investigated, sodium peroxide was found to have been present, and it had apparently become wet by some solution of a sulphur compound packed with it. If the peroxide is put up, as it easily may be, in hermetically sealed tins and packed in mineral wool or infusorial silica, its transportation is without danger.

The attention of hygienists has been called to the consideration of "Modern Explosives in Relation to Health," owing to the fact that within recent years complaints have been made by those

engaged in coal and other mines, where modern "high explosives" were used for blasting, that the fumes resulting from the explosion of these bodies produced deleterious effects, hence, in compliance with the wish of the workpeople, a committee was appointed in September, 1889, by the Durham Coal Owners' Association, consisting of representatives of both masters and men, with two of H. M. Inspectors of Mines, to consider the question, and report whether the fumes produced by the combustion of tonite and roburite were injurious to health, power being given to the committee to call in professional advisers. Mr. Thomas Bell, H. M. Inspector of Mines, was appointed chairman; Professor P. Bedson, chemical adviser, and Drs. Drummond and Hume, medical experts.

Trials were made with tonite, roburite and gunpowder at several collieries, the experiments being conducted in the following manner: First, samples of air were taken at the intake and their composition ascertained by analysis. Then, during the firing of the shots, samples of the vitiated air were taken at the return. The apparatus used for the collection of these samples consisted of a zinc aspirator of about 600 cubic inches' capacity, which, having been filled with water, was slowly emptied, so that the time occupied in displacing the water completely by air was about an hour. The vessel was then securely sealed. A second quantity of air was taken in a glass pipette a quarter of an hour after starting the aspirator, and half an hour after a sample of air in a bottle of 30 cubic inches' capacity was collected, in which the amount of carbonic acid was subsequently determined. The air containing the fumes produced in the immediate vicinity of the shot-firing was collected in a different manner, after unsuccessful attempts had been made to obtain representative samples by means of the zinc aspirators. For this purpose large brass cylinders were employed, 24 inches long and 6 inches in diameter, with a capacity of about 680 cubic inches. At one end of the brass cylinders were two apertures, terminating in narrow brass tubes, securely closed by glass plugs fixed in pressure tubing. These cylinders were first exhausted by an air-pump and then closed in the manner described, being tested carefully with a mercury gauge before each experiment to see if the vacuum had been maintained. A sample of the fumes produced was collected immediately after the firing of the shot by opening a clamp closing one of the apertures to the cylinder, by which means it was quickly filled.

A glass tube filled with glass wool, through which the gases passed before entering the cylinder, removed all solid matter from the mixture of air and gases resulting from the explosion. Naturally, the proportion of air to fumes collected in this manner must vary considerably with different experiments, as the time occupied in reaching the scene of the explosion, and the rate of the air-current through the mine, both influence the rate of diffusion of the fumes. The samples taken for the estimation of carbonic acid, both at the intake and at the return, were examined immediately on reaching the surface. The other two samples of air collected at these two places served—(a) the one collected in the pipette for the estimation of the oxygen, and (b) the sample taken in the zinc aspirator for the complete analysis of the air. Similarly, the samples taken in the brass cylinders at the shot-firing district were used for the determination of oxygen, nitrogen, carbonic acid and also for other gaseous bodies, while smaller samples taken in exhausted pipettes were used for determining the ratio of carbonic acid and of oxygen to nitrogen. These experiments lead to the following conclusions:

The roburite used consisted of a mixture of chlorodinitrobenzene with ammonium nitrate. Three sets of experiments were made with it. (1) The roburite was fired by Bickford's fuze. In all twenty-three shots were fired, there being a total weight of 5.5 pounds of the explosive. Samples of air were taken at both the intake and the return. During the shot-firing four aspirators were filled to examine the fumes. The fumes from four shots were tested especially with blood for carbon monoxide, with negative result. Special examination of the contents of the aspirators for carbon monoxide, nitric oxide and hydrochloric acid showed that all these deleterious gases were absent. A mouse was suspended in a cage in the return during the whole time and subsequently drowned; a spectroscopic examination of its blood gave no indication of carbon monoxide. (2) At the second visit, again twenty-three shots were fired, having a total weight of 4.7 pounds. Samples were collected as before. The air at the return, and the fumes, both showed traces of carbon monoxide. The method used for testing and estimating the CO on this occasion consisted in passing the air through a solution of palladium chloride, which is reduced by carbon monoxide, with the precipitation of metallic palladium. The samples in the brass cylinders from the neighborhood of the shot-firing showed, when examined by this method,

amounts of CO varying from 4.2 to 1.9 parts per 10,000 parts of air, or 0.042 to 0.019 per cent. (3) On the third experiment roburite and gunpowder were tried together, roburite being fired from three places and gunpowder from three places. In all, six charges of the former were fired, weighing 2.25 pounds. The samples taken in the return showed no indication of carbon monoxide, but the fumes, which on this occasion appeared to clear away but slowly, contained CO, the amount being 24 volumes per 10,000 in one sample collected on the face of the coal in the midst of the fumes. A second sample collected on the fumes beginning to lift gave only 1.4 volumes per 10,000, or .014 per cent., thus showing that the air-current acts immediately in clearing away the fumes.

The tonite consisted of equal parts of gun-cotton and barium nitrate, intimately mixed and compressed into cylindrical cartridges with a cylindrical hole at one end. In firing, the cartridge was surrounded by a so-called flame-extinguishing mixture packed in a brown paper bag. As before, Bickford's fuze was used for firing. Two sets of experiments were made, both at South Hetton. On the first occasion nineteen shots were fired, being 6.29 pounds of tonite. The arrangements for collection of the samples were similar to those in the roburite experiments. Examination of the blood of a mouse exposed to the return air showed the presence of CO, but this was the only indication obtained on this occasion of the presence of any deleterious gas. Traces of some combustible gas, either CO or CO and marsh gas, were found in both the intake and return samples. At the second visit thirteen shots were fired, weighing 4.43 pounds. Three cylinders and four pipettes of the fumes were collected. The samples were examined for CO by aspiration through palladium chloride. The results showed it to be absent in the intake air, present in traces in the return, while amounts from 1.9 to 4.8 parts per 10,000 were found in the fumes.

Gunpowder.—Two sets of experiments were conducted with this explosive, one alone and the second in conjunction with roburite. (1) Twenty-six shots were fired, representing 7.38 pounds of gunpowder. A distinctive feature of these experiments was the marked visibility of the fumes produced, as compared with those from tonite and roburite. There was also the characteristic odor of sulphuretted hydrogen. Traces of CO were found in the fumes and also in the return air. (2) These experiments with

gunpowder were conducted simultaneously with a series with roburite, so as to obtain fumes from each produced under the same circumstances. It was found in the experiments conducted at Haswell that, owing to the increased air-current, the samples of fumes were more diluted with air than those obtained in previous experiments. Hence a second series became necessary. Six shots were fired, representing 3.33 pounds of gunpowder. No CO was found in the intake air, and only traces in the air from the return and the fume samples.

As previously stated, the solid matter of the fume was filtered from the gaseous constituents by means of glass wool. On analysis it was found to consist for the most part of finely divided coal. In the case of roburite no indication of the presence of nitrobenzene was observed in the solid matter of the fume. In some of the experiments after firing roburite an odor of bitter almonds was noticed, but beyond this no evidence of the presence of nitrobenzene or a similar body was obtained. The presence of carbon monoxide in the fume, which is not a constituent of the complete combustion of tonite and roburite, was shown to be partly due to the burning of the fuze. Some may also be formed by the passage of the heated carbonic acid over the coal. Analysis of the tonite and roburite used showed them to have the following composition:

TONITE.		No. 52.
Barium nitrate.....		48.21
Potassium nitrate.....		1.77
Gun-cotton		49.21
Moisture		1.58
		<hr/>
		100.00
ROBURITE.		No. 50.
Moisture	1.14	0.66
Ammonium nitrate.....	83.35	86.30
Chlorodinitrobenzene (sol. in ether)....	11.67	11.74
Matter (insoluble in ether and water)..	3.14	1.09
Fixed residue.....	0.70	0.21
		<hr/>
		100.00
		<hr/>
		100.00

No. 51 is a sample of roburite of more recent date than No. 50. Apparently now more ammonium nitrate is added.

The medical report by Drs. Drummond and Hume shows that although they inquired into every case of suspected illness produced by exposure to the fumes, they could find no evidence of acute illness being caused. Of the shot-firers examined only one made any serious complaint, and apparently the dyspepsia from which he suffered was existent before his working with the explosive.

The general conclusions arrived at by the experts were that (1) the fumes produced by tonite and roburite are not more dangerous than those from gunpowder; (2) nitrobenzene is apparently not produced by the combustion of roburite; (3) the carbon monoxide produced is present only in traces; (4) an interval of five minutes should be allowed to elapse before the hewers re-enter the scene of firing; and (5) that, as a portion of the gases in the fumes comes from the fuze, the charges should be fired by electricity.

A more modern explosive than roburite, and one which is similar in nature, is the new "ammonite." The main work of the committee was over before the introduction of this new body; otherwise, in view of the probable general use of ammonite for blasting, it would have been interesting to have examined the fumes produced by its combustion. Ammonite contains 81.5 parts of ammonium nitrate and 8.5 parts of mononitro-naphthalene. It is of equal projectile force to roburite, and superior to tonite. It cannot be exploded by concussion, and burns quietly on an ordinary fire. Its properties are not affected by freezing. It requires rather a strong detonator to produce explosion.—*Industries*, **II**, 182; 1891.

It may be noted here that carbon monoxide, CO, is the most objectionable of the gases found in the products of incomplete combustion or explosion, since as, when inhaled, it combines with materials in the blood corpuscles to form a compound which prevents the blood from performing its proper functions, it exerts a distinct toxic effect. The presence in the atmosphere of one-half of one per cent. of carbonic oxide, or even less than one-half of one per cent. under certain conditions, is fatal to animal life.

Under the title "Les Explosifs Industriels, Le Grison et Les Poussières des Houille,"* M. J. Daniel has collected a large mass

* Lg. 8vo. Vol. I, 348 pp. Vol. II, 444 pp. Whittaker & Co., London, 1895.

of useful and interesting information from original sources which he very properly cites, but while aiming to produce a work useful as a guide to young engineers in the practice of mining, he has dwelt more fully upon the details and theories of explosives than is necessary in a practical guide, and yet not with sufficient fulness for a treatise on explosives, while space is also occupied by irrelevant descriptions of torpedoes, pneumatic guns and other devices. Being a Directeur de la Compagnie des Explosifs Sécurité, M. Daniel is naturally at his best in his discussion of the composition, properties, tests and applications of these recent explosives, and those interested in the preparation or use of flameless explosives, or in the controversy going on between the promoters of the different products offered, will find this part of the work of value. This book bears testimony to the fact that the producers of these French works have not yet discovered what a convenient and labor-saving device an index is.

“The Manufacture of Explosives”* is the title under which Oscar Guttman presents his new work, which is issued in two large volumes with 328 illustrations. The arrangement of this book is one which has been made familiar in Désortian’s *Traité sur la Poudre*, and like this work, Guttman’s first volume is devoted partly to the manufacture of “Black Powder” and partly to a description of the raw materials used in the manufacture of the explosive substances. Volume II treats of gun-cotton, nitro-glycerin, dynamite, nitro-substitution explosives and smokeless powders, while a considerable space is given to apparatus for testing the velocity, pressure and power of explosives, the whole being followed by some seventeen pages of a bibliography which is far from being exhaustive. From his occupation as a builder of works and inventor of apparatus for use in the manufacture of explosives, Mr. Guttman has had excellent opportunities for becoming familiar with the art, but it is not to be expected that much will be published in such a work that has not already been made accessible in periodical or patent publications, so that the work is to some extent historical and suggestive. It is in this light that this work is most valuable to American readers, but it fails to describe American methods and products, though they differ materially from those in vogue in Europe.

* Lg. 8vo, 283 pp. E. Bernard & Cie., Paris, 1893.

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NOTES ON THE LITERATURE OF EXPLOSIVES.*

BY CHARLES E. MUNROE.

No. XXVII.

The "19th Annual Report of H. M. Inspector of Explosives" for the year 1894 states that blasting amberite, cordite, collodion cotton, Westfalite and Von Forster's powder were added to the list of authorized explosives; securite, compressed securite and Denaby powder were dropped from the list, as their manufacture was given up during the year. Nitro paper, plastomentite, electronite, granulite, normal smokeless powder, one variety of Rosslyn smokeless powder, emerald powder, carbonite, smokeless powder and Coopal's powder successfully passed Dr. Dupré's tests and were favorably reported on. Britianite passed the preliminary tests. Schnebelite, three varieties of Rosslyn smokeless powder and one of electronite failed and were rejected.

Schnebelite offers another example of the eventual rejection of a chlorate powder, the powder having passed successfully the preliminary trials as reported December 13th, 1893. During the succeeding year it was submitted to a more prolonged and searching examination, in the course of which, like other chlorate mixtures before tested, it developed certain features pointing to danger. Not only did it show a marked increase in sensibility to percussion and friction, but an appreciable portion of the chlorate became reduced to chloride.

* As it is proposed to continue these notes from time to time, authors, publishers, and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address, *Columbian University, Washington, D. C.*

The sample of electronite which failed showed the peculiar behavior of ammonium salts. This sample consisted of amberite No. 1 (nitro-cellulose, nitro-glycerin, paraffin and shellac) mixed with a considerable proportion of ammonium carbonate, and it suffered serious decomposition, even when kept at ordinary temperature.

An invention having for its object the prevention of the mercury fulminate from escaping from detonators, and which consists either in covering the fulminate with a solid disk of celluloid which fits tightly in the case, or in coating the fulminate with collodion, was reported upon favorably, as was an invention consisting in the introduction of glass tubes filled with a strong solution of ammonia into gunpowder blasting cartridges, with a view to diminishing the effect of the flame produced on firing them.

With the admission of collodion cotton to the "authorized list," a revision in the definition of terms has been made. Hence *officially* collodion cotton consists "of thoroughly purified nitro-cotton (*a*) of which not less than 15 per cent. is soluble in ether-alcohol, and (*b*) which contains not more than 12.3 per cent. of nitrogen," while gun-cotton consists "of thoroughly purified nitro-cotton (*a*) of which not more than 15 per cent. is soluble in ether-alcohol, or (*b*) which contains more than 12.3 per cent. of nitrogen; and with or without carbonate of calcium." The term nitro-cotton is to be "substituted for nitro-cellulose in the definitions of ballistite, gelatine dynamite, blasting gelatine," etc. It is to be regretted that strictly scientific terms were not adopted at the outset, since much confusion of ideas has resulted from the official classification.

Another new feature in designation is in the use of the terms "percussion cap" and "detonator," as a consequence of the two similar accidents which occurred in the drumming of caps in the Royal Laboratory, Woolwich, on July 24th and August 20th. The drum in which the caps are cleaned is of sheet iron, 2 feet in diameter by 7 inches wide, and at the time of the explosion it was charged with 80,000 caps for the 0.303-in. ball cordite ammunition, each containing 0.4 grain of a composition consisting of mercury fulminate, 6 parts; potassium chlorate, 14 parts; antimony sulphide, 18 parts; powder, mealed, 1 part; sulphur, ground, 1 part; together with a quantity of clean sawdust. The drum,

which is turned by hand, had been revolving some three or four minutes when the explosion took place. The explosion partly blew out one side of the drum and scorched the rope mantlet which surrounds it to a height of 6 feet 6 inches, doing no further damage. About 20,000 caps were recovered unexploded. Experiments made to determine the liability of these caps to explode *en masse* showed that this would not occur unless the caps were raised to a high temperature or mixed with loose composition, but as an additional precaution the dividing line between percussion caps and detonators has been raised above that fixed in Annual Report, 1885, pp. 69, 117, and 1890, p. 53, so that now it is ordered that "a *percussion cap* to be one containing a charge not exceeding 0.5 grain of composition, or 0.6 grain of composition when the quantity of fulminate of mercury does not exceed one-fourth of such composition; in any other case the cap will rank as a *detonator*."

In order to identify individual cartridges of explosives, especially when stolen, the German and Belgium governments have recently required that each be marked and numbered. The ingenious method devised by Germany, through which is indicated the factory of origin, date of manufacture, and case in which packed, is described in this report at length with diagrams. After consultation with English manufacturers it was decided that in view of the expense and inconvenience the system entails, and the facility with which the elaborate and costly precautions could apparently be defeated by evil-disposed persons, there was not sufficient warrant for directing the compulsory adoption of such a system.

The comments of Dr. Dupré on an accident at Gover Farm, Abergele, during the burning of rubbish in a grate, illustrates how numerous the causes are which may possibly give rise to explosions. He says: "I have carefully read the further information given, and have also inquired as to what kind of material farmers use that might possibly cause an explosion. I find that some kinds of manures are used consisting of a mixture of saltpeter and ground linseed, or similar cake. As a rule, no doubt, the saltpeter would not be present in sufficiently large proportion to produce an explosion, but it is quite possible that some sample of such manure may have accidentally been mixed with a larger proportion of niter than usual and thus have caused the accident.

It is also possible that the farmer intended to mix a small quantity of manure himself and bought the niter for the purpose."

The repeated spontaneous explosion of fireworks containing sulphur in admixture with potassium chlorate or other chlorate has led to the issuing of an Order in Council prohibiting the manufacture, importation, storage, conveyance or sale of such fireworks. An explosion of some colored lights at Hatton Garden, June 16, appears to have been due to the simple contact of the mixture of barium chlorate and shellac with the gunpowder in the quick-match. Notwithstanding they had been exposed, between two and three years, against the south wall to all weathers, they suddenly took fire. The case bears a strong resemblance to that occurring in the ignition of some green lances at Messrs. Pain's factory, in 1890, and which was clearly shown to be due to the contact of a composition containing barium chlorate with one containing sulphur.*

In recording with their usual fullness the foreign explosions of the year, considerable space is given to the accidents occurring in the United States on *July 4th*, which closes with the following amusing remark, "'Thanksgiving Day' therefore appears to have proved more than usually costly in 1894."

The importation of foreign nitro-glycerin compounds continues to decrease, it having fallen from 1,325,950 lbs. in 1889, the highest mark reached, to 539,802.5 lbs. in 1894, while the importation of detonators increased to 9,765,400 for the year. There were 290 tons of fireworks imported in 1894 against 190 tons in 1893.

It is to be noted that the samples of blasting gelatine tested failed to withstand the test as they should.

In *Dingler's Polyt. Jour.*, **284**, 137-143; 1892, O. Muhlhauser gives the result of his studies on the "Higher Nitric Ethers of Starch." After reviewing the history of the discovery and work done on nitro-starch, he says that it is only recently, by means of a process devised by the "Actiengesellschaft Dynamit Nobel," that it has been possible to manufacture it economically, and thus make it available as an explosive for military purposes. The product prepared by this process has the following composition: $C_6H_8O_3(NO_3)_2$.

* Rept. H. M. Insp. Exp., 1890, p. 35; Special Report No. 94.

The author succeeded in preparing two bodies of the composition $C_6H_{7\frac{1}{2}}O_{2\frac{1}{2}}(NO_3)_{2\frac{1}{2}}$, and $C_6H_7O_4(NO_3)_3$. The starch molecule must consequently be taken twice as large, viz. $C_{12}H_{20}O_{10}$, and the higher members regarded as—

	Per Cent. N.
Tetra-nitro-starch, $C_{12}H_{16}O_6(ONO_2)_4$	11.11
Penta-nitro-starch, $C_{12}H_{15}O_5(ONO_2)_5$	12.75
Hexa-nitro-starch, $C_{12}H_{14}O_4(ONO_2)_6$	14.14

That no nitro-compounds, but true ethers (esters) of nitric acid are formed, is proved:

1st. In that the substances on treatment with sulphuric acid, separate NO_3H . The $O.NO_2$ residue appears thus to be replaced by the sulphuric acid residue.

2nd. On treatment with aqueous ferrous chloride, nitric oxide and soluble starch are regenerated.

3rd. On shaking with sulphuric acid over mercury all nitrogen is split off in the form of NO .

The body prepared by the process above referred to will be taken as tetra-nitro-starch.

This process is carried out as follows: Potato starch is dried at 100° , then ground and dissolved in nitric acid of 1.501 sp. gr. in a suitable vessel made of lead and provided with two jackets cooled by water. A screw agitator causes the acid to circulate. The starch is introduced through an opening in the cover of the combined agitator and digester in the proportion of 10 kilos of starch to 100 kilos of acid, the temperature being maintained between 20° and 25° .

This solution is then led to a precipitating apparatus, which is also surrounded with a cooling jacket and provided with a double perforated bottom, between which is placed gun-cotton to act as a filter. This vessel is filled with spent nitro-sulphuric acid from the nitro-glycerin manufacture, and the solution of starch in nitric acid is sprayed into it through an ejector worked by compressed air, whereby the nitro-starch is precipitated in the form of a fine-grained powder. 500 kilos of spent nitro-sulphuric acid are required to precipitate 100 kilos of starch solution.

The nitro-starch collects on the gun-cotton filter, when the acid solution is run out and drained off through the tap at the bottom of the vessel and below the filter. It is then further freed from acid by pressure and washing till a neutral reaction is attained, and

afterwards it is treated and let stand for 24 hours in contact with 5 per cent. soda solution. The product is then ground until a "milk" is formed, which is filter-pressed and washed with water, and lastly treated with a solution of aniline, so that the pressed cake, which contains about 33 per cent. of water, shall contain 1 per cent. of aniline.

Nitro-starch prepared by the author on the same lines in the laboratory contained 10.96 and 11.09 per cent. of N. It is a snow-white powder, which becomes electrified on rubbing, and is very stable and soluble even in the cold, in nitro-glycerin.

The author also prepared a tetra-nitro-starch containing 10.58 and 10.50 per cent. of nitrogen by pouring into water a solution of starch in nitric acid, which had stood for several days. The body thus produced had all the properties of that prepared by the other process.

Penta-nitro-starch is produced along with some tetra-nitro-starch by adding 20 grms. of rice starch dried at 100 to a mixture of 100 grms. of nitric acid sp. gr. 1.501, and 300 grms. sulphuric acid sp. gr. 1.8. After standing for one hour the mass is discharged into a large quantity of water, and then washed with water and soda solution. The yield was 147.5 per cent. This body was heated with ether alcohol, then the ether was distilled off; the penta-nitro-starch thus became precipitated, the tetra-compound remaining dissolved in the alcohol. The portion insoluble in alcohol contained 12.76 and 12.98 per cent. of nitrogen, and was thus penta-nitro-starch. The other portion contained 10.45 of nitrogen.

Hexa-nitro-starch is the chief product when 40 grms. of dry starch are treated with 400 grms. of nitric acid, sp. gr. 1.501, and allowed to stand for 24 hours, and then 220 grms. of this solution are poured into 600 cc. of sulphuric acid of 66° B. The white powder thus produced contained 13.52, 13.23 and 13.22 per cent. of nitrogen, and therefore consisted principally of penta- and hexa-nitro-starch.

The experiments showed that the bodies prepared by precipitating the nitro-starch by strong sulphuric acid were less stable than those precipitated by water or weak sulphuric acid, the author being of opinion that possibly in the former case a sulpho-group may be formed, which in small quantity might occasion this instability. The following table shows the behavior of bodies prepared in different ways under various conditions.

	Ignition Point C.	Stability.	Per cent. N.	96 per cent. Alcohol.	Ether.	Ether- Alcohol.	Acetic Ether.
1 part nitric, 2 parts sulphuric acid (containing 70 per cent. of water)	175°	Stable.	11.02	Soluble.	Insoluble.	Soluble.	Soluble.
1 part nitric acid, water	170°	Stable.	10.54	Soluble.	Insoluble.	Soluble.	Soluble.
1 part nitric acid, 3 parts concentrated sulphuric acid	152°	Unstable.	12.87	Insoluble.	Insoluble.	Soluble.	Soluble.
1 part nitric acid, 3.5 parts concentrated sulphuric acid	121°	Unstable.	12.50	Insoluble.	Insoluble.	Soluble.	Soluble.
1 part nitric acid, 3 parts concentrated sulphuric acid	155°	Unstable.	13.52	Insoluble.	Insoluble.	Soluble.	Soluble.

The author recommends the production of a smokeless powder by moistening 6 grms. of nitro-jute and 2 grms. of nitro-starch with acetic ether, working into a uniform mixture, and then drying at 50°-56°. This product contained 11.54 per cent. of nitrogen and was very stable.

The *Jour. American Chemical Society*, **18**, 819-846; 1896, publishes under the title of "The Development of Smokeless Powders," the presidential address delivered by Charles E. Munroe, in which, after noting the various inventions and discoveries which made the production of a smokeless powder possible; the improvements in arms and appliances which made a smokeless powder essential; and the composition, properties and methods of manufacture of the various characteristic powders, he says:

"I began my own experiments with smokeless powder manufacture in 1889. At this time the remarkable results published from France and the announcement that that country had adopted a smokeless powder had produced their desired strategic effect. All her rivals were seeking to be equally well equipped, and were hastening to adopt a powder even before its qualities were thoroughly proven. The newspapers contained remarkable accounts of their performances and alleged descriptions of their methods of production which, while interesting as news and conveying valuable suggestions, could not be relied upon as to accuracy in details.

"At the outset, being familiar with the impossibility of securing absolute uniformity and constancy of composition in physical mixtures like gunpowder, and realizing how important this feature

was with our precise modern weapons and when employing an explosive possessing great energy, I determined to attempt to produce a powder which should consist of a single substance in a state of chemical purity. This was a thing which I had not known of having been done, nor have I yet learned that any one else has attempted it. Among the bodies at command the nitric ethers seemed most available, and of these cellulose nitrate seemed for many reasons the most promising.

“There are several of these nitrates (authorities differ as to the number) which differ in their action towards solvents, though all, except the most highly nitrated, are soluble in methyl alcohol. In the commercial production of cellulose nitrates certainly, and so far as I have observed under all circumstances, when nitrating cellulose, the product is a mixture of different cellulose nitrates. Even in the perfected Abel process for making military gun-cotton, as carried out at the Royal Gunpowder Factory at Waltham Abbey, according to Guttman, “Manufacture of Explosives,” 2, 259; 1895, the product contains, as a rule, from 10 to 12 per cent. of nitro-cotton.

“Consequently I began by purifying my dried pulped military gun-cotton, which was done by extracting it with hot methyl alcohol in a continuous extractor, and when this was completed the insoluble cellulose nitrate was again exposed in the drying room. The highly nitrated cellulose was then mixed with a quantity of mono-nitro-benzene, which scarcely affected its appearance and did not alter its powdered form. The powder was then incorporated upon a grinder, by which it was colloidized and converted into a dark translucent mass resembling india rubber. The sheet was now stripped off and cut up into flat grains or strips, or it was pressed through a spaghetti machine and formed into cords, either solid or perforated, of the desired dimensions, which were cut into grains. Then the granulated explosive was immersed in water, boiling under the atmospheric pressure, by which the nitro-benzene was carried off and the cellulose nitrate was indurated so that the mass became light yellow to gray, and as dense and hard as ivory, and it was by this physical change in state, which could be varied within limits by the press, that I modified the material from a brisant rupturing explosive to a slow-burning propellant.

“This is the powder which I styled indurite, and which has been popularly known as the naval smokeless powder.

"I was satisfied that I was justified in starting on this new practice in powder-making when I found, on examination of the samples of foreign military powders which later began to reach me officially, that they were heterogeneous mixtures, as the old gunpowder is, and that they contained matter which was volatile at ordinary temperatures, and when I learned that the nitroglycerol powders cracked from freezing.

"I was still more satisfied when I learned the results of the proving tests which were all made, except the chemical, stability and breaking-down tests, by naval officers detailed for this purpose at the Proving Ground and elsewhere and who had no prejudice in its favor. All of the numerous publications which have appeared about it have issued from headquarters, and I present the matter myself here for the first time.

"I have appended the data from these trials to this address, where on inspection it will be seen that, after development, the powder in use, in successive rounds, gave remarkably regular pressures and uniform velocities. I was informed by the Chief of the Bureau before the firing trials, recorded in the tables, began, that if I could produce a powder giving 2000 feet initial velocity and but fifteen tons pressure it would be a complete success. Inspection of the tables shows that this was more than realized, and that in two successive rounds in the six-inch rapid-fire gun, using twenty-six pounds of my powder and a 100-lb. projectile, the pressures were 13.96 and 13.93 tons and the velocities 2469 and 2456 feet per second respectively, while, according to the Report of the Secretary of the Navy, 1892, page 26, 'The powder manufactured for use in the six-inch rapid-fire guns was stored at Indian Head Proving Ground, through a period of six months, covering a hot summer, and at the end of the time showed no change in a firing test.'

"On page 25 Secretary Tracy says: 'It became apparent to the Department early in this administration, that unless it was content to fall behind the standard of military and naval progress abroad in respect to powder, it must take some steps to develop and to provide for the manufacture in this country of the new smokeless powder, from which extraordinary results had been obtained in Europe. With this object, negotiations were at first attempted looking to the acquisition of the secret of its composition and manufacture. Finding itself unable to accomplish this, the De-

partment turned its attention to the development of a similar product from independent investigation. The history of these investigations and of the successful work performed in this direction at the torpedo station has been recited in previous reports. It is a gratifying fact to be able to show that what we could not obtain through the assistance of others we succeeded in accomplishing ourselves, and that the results are considerably in advance of those hitherto attained in foreign countries.'

"From this survey we see that all the smokeless powders that have met with acceptance and proved of value as ballistic agents, with the exception of Indurite, are mixtures of one or more of the cellulose nitrates, or mixtures of these bodies with nitro-glycerin or some other oxidizing agent, like barium nitrate, and a restrainer or with a nitro-substitution compound, and that all have been condensed or hardened into a rubber-like or celluloid-like form, by which, even under the high pressures which obtain in the gun, they are expected to undergo combustion only, and that at a moderate and regular rate.

"In thus condensing the material and in determining the best form of grain, it will be observed that we have been guided by the experience gained in the compression of gunpowder, and we have been able to effect this as we have by the experience gained in the development of celluloid, and we have been able to manipulate our product and shape it into grains only by adopting the methods and machines developed in the manufacture of food, while we have been able to test our product and check our results, and thus ensure a more rapid and certain advance by the constant use of the pressure gauge and velocimeter. In my opinion, if these resources had not been at command and available the smokeless powder industry would not yet exist.

"From what has been said it may properly be inferred that we seek in these new powders all the virtues of the old gunpowder with the addition that the new powder shall be smokeless, impart higher velocities while producing no greater pressures, and that less of it shall be required to do the work. These requirements may be summed up as follows:

"The conditions that a smokeless powder suitable for a propellant should fulfill are:

"1. That it shall be physically and chemically uniform in composition.

“ 2. That it shall be stable and permanent under the varying conditions of temperature and humidity incident to service storage and use for all time.

“ 3. That it shall be sufficiently rigid to resist deformation in transportation and handling.

“ 4. That it shall produce a higher or as high a velocity with as low a pressure as the service charge of black powder for a given piece.

“ 5. That it shall be incapable of undergoing a detonating explosion.

“ 6. That the products of its combustion shall be nearly, if not quite, gaseous, so that there shall be no residue from it and little or no smoke.

“ 7. That it shall produce no noxious or irrespirable gases or vapors.

“ 8. That it shall not unduly erode the piece by developing an excessive temperature.

“ 9. That it shall be as safe as gunpowder in handling and loading.

“ 10. That it shall be no more than ordinarily dangerous to manufacture.

“ Most of these requirements have been satisfied in several of the powders, but time alone can determine the question of absolute stability, and especially as the comparison is instituted with gunpowder, which has been under observation for over 500 years.

“ We can and do apply tests whose results give us some confidence, as I did when I exposed indurite wrapped in felt in an iron vessel to a temperature of 208° F. for six hours without its undergoing change, and again at a temperature of 212° F. for twenty hours before any signs of change were observed, and again to 5° F. without its being affected.

“ In fact, from the outset I have advised the most rigid tests being applied, and drew up the following scheme for the Navy Department in July, 1891, by which to test indurite:

“ The most important requisite of powder, after passing the proof test, is that it shall retain its characteristics under all the conditions of storage or transportation which may obtain in the service, or that, if any change does take place, it shall not cause the powder to develop under the ‘proof’ conditions any greater pressure than it did at the time of proving, and that such falling

off in velocity as may result from this change in the powder shall not be relatively greater than that which obtains for service black powder, and shall be uniform for the same conditions of exposure.

“In providing for this test I would first prove a ten-pound lot to determine the maximum weight that will come within the limits fixed for pressure and velocity, and then I would load 1000 Winchester 30.1 cal. and 1000 Mannlicher shell with a charge some grains (say five) less than the maximum, so as to be doubly safe in case the pressure should become increased through the treatment to which the powder is subjected.

“The loading should be done with extreme care by skilled workmen in an especially clean and uniformly heated and dried room. The charges should be weighed on chemical balances and with all the precautions surrounding an analytical operation. The balls should be weighed and gauged, and the shell should be gauged so as to secure as nearly absolute uniformity as possible, while the caps and priming (if used) and wads should be identical for each shell of each 1000 lot.

“These being prepared, I would pack these ball cartridges precisely as if ready for issue to the service, and then I would store 385 Winchesters and 385 Mannlichers in the regular magazine at the Naval Torpedo Station, and the same number of the same kind in the regular magazine at the Naval Ordnance Proving Ground. I would then draw from the magazine at the Torpedo Station twenty-five Winchesters and twenty-five Mannlichers and fire them, using the muskets and measuring instruments which are to be used throughout the trials, and I would repeat this trial every month for three years, firing ten rounds of each form of ammunition and using the same muskets and instruments throughout. At the same time I would have an identical set of tests made at the proving ground, the same precautions being taken there regarding the instruments and tools. Throughout the tests a close watch should be kept on the magazine by means of maximum and minimum thermometers, so that if abnormal results are obtained in firing it may be known whether or not any abnormal conditions have obtained in the magazine. This series of tests will consume 1540 rounds. It would, in my judgment, be of much value to store with these cartridges and fire with them an equal number of charges of standard service black powder, to be used as a standard for reference by which

any error in the observations or defects in the instruments may be detected.

“ I would take eighty rounds of the Winchesters and eighty of the Mannlichers and place them in an oven heated to 140° F. or thereabouts. At the end of one month twenty of each are to be drawn out, and this to be repeated each month for four months. One-half of each form should be proved at the Torpedo Station and the other half at the proving ground.

“ I would take eighty rounds of the Winchesters and eighty of the Mannlichers and subject them for two weeks to the freezing temperature, then for two weeks to a temperature of about 140° F., and then draw twenty of each, and this should be continued until the last forty drawn out have been exposed for eight weeks to freezing and eight weeks to the high temperature. The firing trials with these should be made as with preceding ones.

“ The remaining shell should be stored in the regular magazine, to be used in any test case which may arise or in any manner suggested by the results obtained in the tests described above.

“ In the meantime tests could be made with the hand-cut S. P. for the capacity of the powder to resist crumbling and dusting during transportation, and the tendency of the fixed ammunition to explode *en masse* by the impact of projectiles or by the explosion of a single cartridge in the midst of a box filled with them. The first can be effected by taking a pound or a kilogram of carefully sifted powder, placing in a copper vessel which it only partly fills, and attaching it to a shaft so that it will be continually and violently shaken, and allowing this to go on every working day for a week. The powder can then be sifted, using the same mesh as before, the weight of the dust found and the percentage of dusting for the given circumstances determined.

“ In the trials for tendency to explode *en masse* fifty or forty-five caliber ammunition can be used, and the weights of charges need not be very precise, but the ammunition should be packed in, as nearly as possible, the same way as would obtain in service practice.

“ We have seen that the development of smokeless powder has been rendered necessary by the improvement in the gun. It now appears that in consequence of the possession of the powder we must further improve the gun, for we cannot in our present guns utilize all the energy now available. Experiments looking to

this have been going on in France, where in a Canet 10-cm. gun of 80 calibers, with a charge of 12.35 pounds of powder and a projectile weighing 28.66 pounds, there was obtained the extraordinary muzzle velocity of 3366 feet per second, while the maximum pressure was 18.91 tons per square inch. Longridge, an English authority, deprecates the lengthening of the gun, as it becomes too unwieldy, and he advocates utilizing the energy by strengthening the gun so it will endure greater pressures and then using larger charges. He points out that if this Canet gun were reduced to 45 calibers and strengthened we could obtain from it the same enormous muzzle velocity by increasing the charge to $13\frac{1}{2}$ pounds, though the pressure would rise to 25 tons per square inch.

“What the result will be where authorities of standing disagree is impossible to foresee, but the fact is demonstrated that the powder is now more highly developed than the gun, and that while seeking for smokelessness, we have secured a propellant which is capable of producing much higher velocities than gunpowder, with all the additional advantages of flat trajectory, increased danger area, greater accuracy and greater range, which follow as consequences.”

Messrs. William Macnab and E. Ristori have carried out a long series of experiments with explosive compounds for the purpose of studying chemical reactions at high temperatures and pressures, and of elucidating certain thermal constants relating chiefly to the specific heat of gases under such conditions, and a portion of their results is published in the *Proc. Roy. Soc.*, **56**, 8-19; 1894, under the title of “Researches on Modern Explosives.”

For these experiments they have principally used nitro-glycerin, nitro-cellulose, and several combinations of these two bodies which are used for smokeless gunpowders, for the reason that such modern explosives offer the advantage of not only presenting comparatively simple chemical reactions, owing to the absence of solid residue, but also of enabling considerable variations to be made in their composition so as to vary the proportions of the elements reacting.

In this preliminary communication they propose chiefly to indicate the results obtained in the measurement of the heat evolved by explosion and of the quantity and composition of the gases produced by this metamorphosis.

They have also made considerable progress towards the determination of the actual temperature of explosion, and have succeeded in recording these high temperatures by photographic means, but these results are to be made the subject of another communication at an early date.

The great secret of all these modern explosives seems to be that by suitable means they are made into a solid substance, thus avoiding any porosity, and it appears probable that by doing so even the most powerful explosive can be mastered, so that, burning regularly from the surface, the rate of combustion can be controlled so as to avoid detonation.

This constitutes the most striking feature of the modern smokeless gunpowders, especially of those containing nitro-glycerin. If certain sized cubes, strips or cords of such powders are fired in a certain gun and the length of this gun does not allow of sufficient time during the travel of the shot for the explosive to be entirely consumed, the unburnt residue of the charge will be found to be of the same shape, whether cubes, strips or cords, only reduced in size; thus proving the most perfect surface combustion of these explosives.

It is thus possible to determine accurately what quantity of explosive, and what surface of combustion for the same, will be required, in order to obtain certain results in a certain gun, thus avoiding waste of powder.

The insensitiveness of modern smokeless powder was illustrated on the occasion of a disastrous fire which occurred in May, 1890, at the factory of Avigliana, Italy, where large quantities of ballistite were manufactured. In one building twelve tons of this explosive were collected and various operations of manufacture were performed. By accident some of it took fire, and the whole quantity was burnt in a few seconds. Though this powder was made of nitro-glycerin and nitro-cellulose, and though the amount was so large that had it been black powder it would have caused destruction for many miles around, still there was no explosion of any kind; none of the machinery was in any way damaged, and the wood was barely charred.

The explosives used in these experiments can be divided into three classes:

1. Those consisting of nitro-lignin or nitro-cellulose (not gelatinized) mixed or impregnated with a suitable nitrate, and mixed

with coloring matters and some other substances for the purpose of retarding the rate of combustion.

2. Those consisting of purified nitro-lignin or nitro-cellulose gelatinized by a suitable process, and with or without the addition of nitro-benzene or other suitable nitrates.

3. Those consisting of nitro-cellulose combined with nitro-glycerin, with the addition of aniline, camphor, vaseline, or other kindred substances.

The experiments were carried out in two closed vessels of different dimensions and construction—a large one capable of standing high pressures and a small one for calorimetric work.

The large one consists of a steel cylinder of great thickness, closed at both ends by conical screw-plugs. One plug is provided with a crusher-gauge of the well known pattern, by which the compression of a small cylinder of copper serves to measure the pressure developed. The other plug is provided with an insulated conical core, by means of which an electric current can be passed for the purpose of firing the charge. A small hole on the side of the cylinder, bushed with iridium-platinum and closed by a coned screw-plug, serves to control the escape of the gases produced by the explosion. The capacity of the chamber was carefully measured and was found to be 247.6 cc.

The small vessel is of the same pattern as used by Berthelot, and was made by Golaz, of Paris. It has given great satisfaction and is in excellent order, although it has been used for more than two hundred explosions. This bomb, which is made of mild steel and is cylindrical in shape, consists essentially of three parts—a bowl; a conical lid, which is accurately ground into the bowl; and a tightening cap, which screws on to the bowl over the lid. There is a small hole in the lid provided with a delivery tube, which can be opened and closed by means of a finely threaded conical plug. There is also an insulated platinum cone inserted from underneath in the lid, which admits of the charge in the bomb being fired by a platinum wire heated to redness by electricity. From the lid depend platinum supports which carry a platinum capsule, in which the explosive is placed and suspended in the middle of the chamber. The capacity of this bomb is 488 cc., and the total weight, including a small stand, when ready for immersion in the calorimeter, is 5633.28 grams.

The calorimeter is made of thin sheet brass, and a helicoidal

stirrer of the same metal (Berthelot's pattern), driven by a small electromotor during the experiment, serves to thoroughly mix the water. The calorimeter stood in the center of an annular water-jacket covered with felt. The quantity of water used in the calorimeter each time was 2500 grams, and the equivalent in water of the bomb, stirrer and calorimeter, due allowance having been made for the different specific heats of the different metals, is 623.4 grams.

The different thermometers employed were specially made by Casella, capable of being read to 0.005 of a degree centigrade, and the weights of their stems, bulbs and mercury were known.

Various experiments were made in the large vessel, especially for the purpose of determining the pressure of the gases under different densities of charge. These trials were carried out in a field, the bomb being lowered into a hole in the ground before firing. Various difficulties were encountered, and in one experiment considerable damage was done by the heated gases effecting their escape at the moment of explosion and "washing away" part of the thread of one of the screw-plugs.

With the density of loading of $\Delta = 0.1$, *i. e.*, with a charge of 24.76 grams, the average of the pressures measured was 6.3 tons per square inch; with density $\Delta = 0.2$ the pressure rose to 15 tons, and with $\Delta = 0.3$ the pressure increased to 25 tons. These results are very similar to those published by Sir A. Noble, F.R.S.

With the small bomb were ascertained the amount of heat generated by the explosion, the volume and composition of the permanent gases resulting, and the quantity of aqueous vapor produced. As most of the explosives contained no mineral matter beyond a trifling percentage of "ash," it has been possible to analyze them in this way, the products of explosion when calculated from the analysis and volume of permanent gas and aqueous vapor agreeing closely with the weight of matter in the bomb before firing. A few of the explosives left a carbonaceous or mineral residue, but these will be specially noticed further on in connection with the table of the results.

The heat evolved was measured by placing the bomb containing the charge of explosive in the calorimeter containing 2500 grams of water, and it was arranged that the temperature of the air, the water-jacket, and the calorimeter closely approximated each other. The stirrer was set in motion, and the thermometer

in the calorimeter was read with a kathetometer. Observations of the temperatures were made every minute for the five minutes preceding the firing of the charge, and continued at intervals of a minute until the maximum was reached and for five minutes longer. The correction for loss of heat due to radiation of heat during the experiments amounted in general to about 0.01 of a degree. The increase in temperature varied from about 1° to $2\frac{1}{2}^{\circ}$ C., according to the charge and explosive used.

The gas generated by the explosion was passed through weighed drying tubes connected with the valve on the lid of the vessel, and then collected and measured in a calibrated glass cylinder over mercury. The reading of the barometer and thermometer was noted, and the volume reduced to 0° C. and 760 mm.

The water was determined by immersing the bomb in a vessel containing boiling water. A three-way glass stop-cock intervened between the valve of the bomb and the drying tubes, and the other end of the drying apparatus was connected with a water vacuum pump.

The other branch of the three-way tap was connected with a separate drying apparatus. When the water surrounding the bulb was boiling, by starting the vacuum pump the steam and water were drawn into the absorbing apparatus; after a good vacuum had been made in the bomb the three-way tap was turned so that dry air rushed in, then connection was made with the drying apparatus, the bomb again exhausted, and so on, alternately, until (as experience showed) all the water had been removed from the bomb and collected in the drying tubes, which were then weighed. The weights of water thus obtained were calculated for comparison into volumes of H_2O gas at 0° C. and 760 mm.

The analyses of gas were carried out in duplicate in Dittmar's apparatus as improved by Lennox.

In most of the experiments the bomb, previous to firing, was exhausted and the amount of residual pressure, varying from 24 to 40 mm., noted on closing it. The amount of air corresponding to these pressures left in the bomb has the effect of increasing the heat generated by a small quantity amounting to five to seven calories. This quantity being within the limits of error of the calorimetric observation, no correction was made for the same, but the quantity of residual air was taken into account when

comparing the weights of the products found with the weight of the explosive used. Thus in Tables I and II the volumes of gas of the given composition and of aqueous vapor were obtained from the given weight of explosive increased by the weight of the air corresponding to the vacuum indicated. When firing in an exhausted bomb it was found necessary to have the explosive surrounding the firing wire in comparatively small pieces, in order to ensure ignition of the whole charge.

TABLE I.—INDICATING THE QUANTITY OF HEAT, ALSO THE VOLUME AND ANALYSIS OF THE GAS DEVELOPED PER GRAM WITH DIFFERENT SPORTING AND MILITARY SMOKELESS POWDERS NOW IN USE.

Name of explosive.	Calories per gram.	Permanent gases.	Aqueous vapor.	Total volume of gas calculated at 0° and 760 mm.	Per cent. composition of permanent gases.					Coefficient of potential energy.
					CO ₂ .	CO.	CH ₄ .	H.	N.	
		Cc. per gram.	Cc. per gram.	Cc. per gram.						
EC powder, English	800	420	154	574	22.9	40.6	0.5	15.5	20.5	459
SS sporting powder, English....	799	584	150	734	18.2	45.4	0.7	20.0	15.7	586
Troisdorf, German	943	700	195	895	18.7	47.9	0.8	17.4	15.2	844
Rifleite, English..	864	766	159	925	14.2	50.1	0.3	20.5	14.9	799
BN, French	833	738	168	906	13.2	53.1	0.7	19.4	13.6	755
Cordite, English manufacture....	1253	647	235	882	24.9	40.3	0.7	14.8	19.3	1105
Ballistite, German manufacture....	1291	591	231	822	33.1	35.4	0.5	10.1	20.9	1061
Ballistite, Italian and Spanish manufacture....	1317	581	245	826	35.9	32.6	0.3	9.0	22.2	1088

Table I gives the principal results obtained with the several gunpowders above mentioned, Tables II and III give the results obtained with samples of ballistite made with different proportions of the component parts, Table IV indicates the effect of firing different weights of the same explosive in a closed vessel from which the air has not been exhausted, and Table V gives the original elementary composition of several explosives compared with the products of combustion, both being represented as weights.

With the exception of the results given in Table IV, all the others were obtained from the firing of 4 grams of the explosive.

In Tables I and II we have expressed the results of firing some powders now in use, as well as certain specially prepared powders, so as to show the quantity of heat and the volumes and analyses of the gases produced, and have in the column headed "Coefficient of potential energy," given figures which serve as a measure of comparison of the power of the several explosives. These figures are the products of the number of calories by the volumes of gas, the last three figures being suppressed in order to simplify the results.

In the case of EC and SS a certain amount of mineral residue was left, but this was not determined.

TABLE II.—INDICATING THE QUANTITY OF HEAT, ALSO THE VOLUME AND ANALYSIS OF THE GAS DEVELOPED PER GRAM WITH NITRO-GLYCERIN, NITRO-CELLULOSE, AND WITH SEVERAL DIFFERENT COMBINATIONS OF THESE TWO EXPLOSIVES MADE AT ARDEER FACTORY.

Composition of explosive.	Calories per gram.	Permanent gas.	Aqueous vapor.	Total volume of gas calculated at 0° and 760 mm.	Per cent. composition of permanent gases.						Coefficient of potential energy.
					CO ₂ .	CO.	CH ₄ .	.	H.	N.	
A. Nitro-glycerin.	1652	Cc. per gram. 464	Cc. per gram. 257	Cc. per gram. 741	63.0	..	..	4.0	..	33.0	1224
B. Nitro-cellulose (nitrogen = 13.30 per cent.)	1061	673	203	876	22.3	45.4	0.5	..	14.9	16.9	929
C. 50 per cent. (nitro-cellulose (N=12.24 per cent.). 50 per cent. nitro-glycerin.	1349	568	249	817	36.5	32.5	0.2	..	8.4	22.4	1102
D. 50 per cent. (nitro-cellulose (N=13.3 per cent.). 50 per cent. nitro-glycerin.	1410	550	247	797	41.8	27.5	..	..	6.0	24.7	1124
E. 80 per cent. nitro-cellulose (N=12.24 per cent.). 20 per cent. nitro-glycerin.	1062	675	226	901	21.7	45.4	0.1	..	15.7	17.1	957
F. 80 per cent. nitro-cellulose (N=13.30 per cent.). 20 per cent. nitro-glycerin.	1159	637	227	864	26.6	40.8	0.1	..	12.0	20.5	1001
G. 35 per cent. nitro-cellulose (N=13.30 per cent.). 5 per cent. vaseline. 60 per cent. nitro-glycerin.	1280	627	236	863	26.7	39.8	0.5	..	12.8	20.2	1105

TABLE III.—SHOWING THE HEAT DEVELOPED BY EXPLOSIVES CONTAINING NITRO-GLYCERIN AND NITRO-CELLULOSE IN DIFFERENT PROPORTIONS.

Composition of Explosives.			Calories per gram.
Nitro-cellulose (N = 13.3 per cent.).		Nitro-glycerin.	
100 per cent. (dry pulp).		0	1061
100 " " (gelatinized).		0	922
90 " "		10 per cent.	1044
80 " "		20 " "	1159
70 " "		30 " "	1267
60 " "		40 " "	1347
50 " "		50 " "	1410
40 " "		60 " "	1467
0 " "		100 " "	1652
Nitro-cellulose (N = 12.24 per cent.).		Nitro-glycerin.	
80 per cent.		20 per cent.	
60 " "		40 " "	
50 " "		50 " "	
40 " "		60 " "	
Nitro-cellulose (N = 13.3 per cent.).		Vaseline.	
55 per cent.		5 per cent.	
35 " "		5 " "	
		Nitro-glycerin.	
		40 per cent.	
		60 " "	1134 1280

Troisdorf leaves a slight, and Rifleite and BN a considerable, carbonaceous residue, part of it adhering so tenaciously to the bomb that an exact determination was not made.

In the other experiments recorded in Tables I and II the degree of accuracy of the results may be gauged by the fact that the average weight of the products of explosion, calculated from the results found, amounts to 99.7 per cent. of the weight of the explosive fired, the extreme limits being 100.5 and 98.9 per cent.

In Table II the comparison of the pairs of results from explosives made with lower and more highly nitrated nitro-cellulose shows that the use of the highly nitrated cellulose increases the quantity of heat developed and diminishes the volume of gas. The composition of the permanent gases is also altered, as might be expected, there being an increase in carbon dioxide and decrease in carbon monoxide and hydrogen.

The similarity in the volumes of gas produced and the composition of the permanent gases in the case of experiments F and G is worthy of note when the great difference in the original component ingredients of the explosives is borne in mind.

Table III shows clearly the increase of heat due to increased percentage of nitro-glycerin, as well as the difference of heat evolved from explosives containing nitro-cellulose of different degrees of nitration.

The diminution in quantity of heat (about 200 calories) which the replacement of 5 per cent. of nitro-cellulose by vaseline makes is also very striking.

Table IV shows the part played by the oxygen of the air in the bomb; when a smaller proportion of explosive in comparison with the air is present the combustion is more complete, and the heat evolved is greater, and the composition of the gases is correspondingly modified.

TABLE IV.—SHOWING THE HEAT DEVELOPED AND THE ANALYSIS OF THE PERMANENT GAS PRODUCED IN A CLOSED VESSEL FROM WHICH THE AIR HAS NOT BEEN EXHAUSTED—THE EXPLOSIVE BEING IN EVERY CASE BALLISTITE OF ITALIAN MANUFACTURE.

Charge.	Calories per gram.	Analysis of the permanent gas.			
		CO ₂ .	CO.	H.	N.
2 grams	1587	37.0	17.6	3.2	42.2
3 " 	1485	36.4	22.0	4.6	37.0
4 " 	1446	36.2	24.6	6.1	33.1
5 " 	1415	36.2	26.0	7.2	30.6
6 " 	1380	36.3	27.0	7.9	28.6

Traces of CH₄ were found, but in this series of experiments the quantity of this gas was not determined.

Table V, the elementary composition of some of the explosives, along with the percentage composition of the products of explosion by weight, is given.

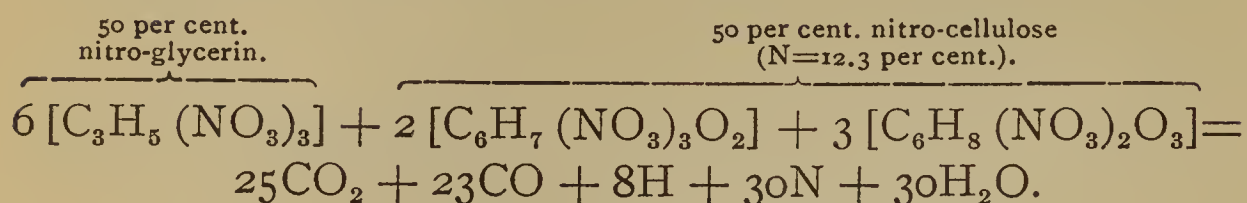
TABLE V.—SHOWING THE ORIGINAL COMPOSITION AND METAMORPHOSIS OF NITRO-CELLULOSE, NITRO-GLYCERIN, AND OF SEVERAL GUNPOWDERS MADE BY COMBINATIONS OF THESE TWO EXPLOSIVES.

Nature and description of explosives.	Per cent. composition by weight.				Per cent. products of combustion by weight.						
	Carbon, C.	Oxygen, O.	Hydrogen, H.	Nitrogen, N.	Carbonic acid, CO ₂ .	Carbonic oxide, CO.	Marsh gas, CH ₄ .	Oxygen, O.	Hydrogen, H.	Nitrogen, N.	Water, H ₂ O.
A. Nitro-glycerin.	15.7	63.0	2.3	18.8	57.6	..	..	2.7	..	18.8	20.7
B. Nitro-cellulose (nitrogen = 13.3).	24.58	57.68	2.73	13.6	29.27	38.52	0.24	..	0.86	13.6	16.30
C. 50 per cent. nitro-cellulose (N = 12.24 per cent.). 50 per cent. nitro-glycerin.	21.15	60.67	2.67	15.58	41.0	23.1	0.08	..	0.4	15.58	20.01
D. 50 per cent. nitro-cellulose (N = 13.30 per cent.). 50 per cent. nitro-glycerin.	20.47	61.23	2.49	16.35	45.3	19.0	..	..	0.3	16.35	19.90
E. 80 per cent. nitro-cellulose (N = 12.24 per cent.). 20 per cent. nitro-glycerin.	24.37	58.98	2.98	14.0	28.9	38.4	0.05	..	1.0	14.0	18.2
F. 80 per cent. nitro-cellulose (N = 13.30 per cent.). 20 per cent. nitro-glycerin.	23.11	58.98	2.71	15.84	33.4	32.6	0.04	..	0.7	15.84	18.2
G. 35 per cent. nitro-cellulose (N = 13.30 per cent.). 5 per cent. vaseline 60 per cent. nitro-glycerin.	22.2	59.0	2.88	15.46	33.0	31.3	0.2	..	0.7	15.46	19.0
H. Cordite, English manufacture.	22.91	57.72	2.95	15.19	31.76	32.68	0.32	..	0.86	15.19	18.08
K. Ballistite, Italian and Spanish manufacture.	21.47	60.83	2.68	15.80	41.11	23.76	0.12	..	0.47	15.8	19.69

The composition of the samples has been calculated from the "bomb" analyses; as an example, one of the explosives and its decomposition may be represented approximately by the following equation.

They have assumed the nitro-cellulose to consist of a mixture of di- and tri-nitro-cellulose in proportion corresponding to the nitrogen as found by analysis.

The equation for experiment C may be taken as follows:



The composition of this explosive, calculated from the foregoing formula and found by analysis, is as follows:

	FORMULA.	ANALYSIS.
C	21.2	21.15
O	60.8	60.67
H	2.5	2.67
N	15.5	15.58
	<hr/>	<hr/>
	100.0	100.07

These are some of the principal features noticeable in a preliminary survey of these experiments. They are continuing their investigations on the lines indicated in the paper, and are especially endeavoring to measure the actual temperature of explosion under varying conditions, and it is hoped that the result obtained will throw some light on the chemical and physical properties of many gases at high temperatures and under considerable pressures, and, at the same time, be useful in the practical application of explosives.

The "Researches on Explosives," on which Capt. A. Noble and Sir F. Abel have been engaged for very many years, have had their scope so altered and extended by the rapid advances which have been made in the science of explosives that they have been unable to lay before the Society the results of the many hundreds of experiments carried out under varied conditions. They have been desirous of clearing up some difficulties which have presented themselves with certain modern explosives when dealing with high densities and pressures, but the necessary investigations have occupied so much time that Capt. Noble has issued a preliminary note in the *Proceedings Royal Society*, 56, 205-221; 1894, trusting before long to be able to submit a more complete memoir.

A portion of their reasearches includes investigations into the transformation and ballistic properties of powders varying greatly

in composition, but of which potassium nitrate is the chief constituent. In this preliminary note it is proposed to refer to powders of this description chiefly for purposes of comparison, and to devote attention principally to gun-cotton and to those modern explosives of which gun-cotton forms a principal ingredient.

In determining the transformation experienced during explosion, the same arrangements for firing the explosive and collecting the gases were followed as are described in their earlier researches,* and the gases themselves were, after being sealed, analyzed either under the personal superintendence of Sir F. Abel or of Prof. Dewar.

The heat developed by explosion and the quantity of permanent gases generated were also determined, as described in their researches, but the amount of water formed plays so important a part in the transformation that special means were adopted in order to obtain this product with exactness.

The arrangement employed was as follows: After the explosion the gases formed were allowed to escape through two U tubes filled with pumice stone and concentrated sulphuric acid; when the gases had all escaped the explosion cylinder was opened and the water deposited at the bottom of the cylinder was collected in a sponge, placed in a closed glass vessel and weighed. The cylinder was then nearly closed and heated, and a measured quantity of air was, by means of an aspirator, drawn slowly through the U tubes till the cylinder was perfectly dry. This was easily ascertained by observing when moisture was no longer deposited on a cooled glass tube through which the air passed.

The U tubes were then carefully weighed, the amount of moisture absorbed determined and added to the quantity of water directly collected. The aqueous vapor in the air employed for drying was, for each experiment, determined and deducted from the gross amount.

Numerous experiments were made to ascertain the relation of the tension of the various explosives employed, to the gravimetric density of the charge when fired in a close vessel, but this subject is too large to be treated of in a preliminary note, and besides

**Phil. Trans.*, 165, 61.

approximate values have already been published* for several of the explosives with which they have experimented.

With certain explosives the possibility or probability of detonation was very carefully investigated. In some cases the explosive was merely placed in the explosion vessel in close proximity to a charge of mercuric fulminate, by which it was fired, but the most satisfactory method was to place the charge in a small shell packed as tightly as possible, the shell then being placed in a large explosion vessel and fired by means of mercuric fulminate. The tension in the small shell at the moment of fracture and the tension in the large explosion vessel were in each experiment carefully measured.

Capt. Noble does not consider the presence of a high pressure with any explosive as necessarily denoting detonation. Both cordite and gun-cotton have developed enormous pressures, close upon 100 tons per square inch (about 15,000 atmospheres), but he has not succeeded in detonating the former explosive, while gun-cotton can be detonated with the utmost ease. It is obvious that if we suppose a small charge fired in a vessel impervious to heat, the rapidity or slowness of combustion will make no difference in the developed pressure, and that pressure will be the highest of which the explosive is capable, regard being of course had to the density of the charge. A small charge is supposed, because if a large charge were in question and explosion took place with extreme rapidity, the nascent gases may give rise to such whirlwinds of pressure that any means we may have of registering the tension will show pressures very much higher than would be registered were the gases, at the same temperature, in a state of quiescence. Innumerable proofs have been had of this action, but it is evident that in a very small charge the nascent gases will have much less energy than in the case of a large charge occupying a considerable space.

The great increase in the magnitude of the charges fired from modern guns has rendered the question of erosion one of great importance. Few, who have not had actual experience, have any idea how rapidly with very large charges the surface of the bore is removed. Great attention has therefore been paid to this point, both in regard to the erosive power of different explosives and in

* Noble, *Internal Ballistics*, 33; 1892, and *Proc. Roy. Soc.*, 52, 128.

regard to the capacity of different materials (chiefly different natures of steel) to resist the erosive action. The method adopted consisted in allowing large charges to escape through a small vent. The amount of the metal removed by the passage of the products of explosion, which amount was determined by calibration, was taken as a measure of the erosive power of the explosive.

Experiments were also made to determine the rate at which the products of explosion part with their heat to the surrounding envelope, the products of explosion being altogether confined.

Turning now to ballistic results, the energies which the new explosives are capable of developing, and the high pressures at which the resulting gases are discharged from the muzzle of the gun, render length of bore of increased importance. With the object of ascertaining with more precision the advantages to be gained by length, the firm to which Captain Noble belongs has experimented with a 6-inch gun of 100 calibers in length. In these experiments the velocity and energy generated has not only been measured at the muzzle, but the velocity and the pressure producing this velocity have been obtained for every point of the bore, consequently the loss of velocity and energy due to any particular shortening of the bore can be at once deduced. These results have been obtained by measuring the velocities every round at sixteen points in the bore and at the muzzle. These data enable a velocity curve to be laid down, while from this curve the corresponding pressure curve can be calculated. The maximum chamber pressure obtained by these means is corroborated by simultaneous observations taken with crusher gauges, and the internal ballistics of various explosives have thus been completely determined.

Commencing with gun-cotton, with which a very large number of analyses were made, with the view of determining whether there was any material difference in the decomposition dependent upon the pressure under which it was exploded, two descriptions were employed: one in the form of hank or strand, and the other in the form of compressed pellets. Both natures were approximately of the same composition, of Waltham Abbey manufacture, containing in a dried sample about 4.4 per cent. of soluble cotton and 95.6 per cent. of insoluble. As used, it contained about 2.25 per cent. of moisture.

The following were the results of the analyses of the permanent gases. They are placed in five series, viz.: First, analyses show-

ing the decomposition of the strand or hank gun-cotton; second, analyses showing the decomposition of pellet gun-cotton; third and fourth, examples of the decomposition of strand and pellet gun-cotton when exploded by means of mercuric fulminate; and fifth, a series showing the decomposition experienced by pellet gun-cotton saturated with from 25 to 30 per cent. of water, and detonated by means of a primer of dry gun-cotton and mercuric fulminate.

In Tables I and II the marked manner in which the carbon dioxide increases with the pressure, and which has been heretofore noted for gunpowder, is again exhibited. It will be observed that in Table I the volumes of carbon dioxide and carbon monoxide are nearly exactly reversed; again, considering that the composition of the pellet and strand gun-cotton is practically the same, the distinct difference between the proportions of these products in the two series is sufficiently remarkable. It not improbably is connected with the rapidity of combustion of the two samples. Another striking peculiarity is the manner in which CO₂ is increased (as exhibited in Table V) when saturated pellet cotton is detonated.

I.—RESULTS IN VOLUMES OF THE ANALYSES OF THE PERMANENT GASES GENERATED BY THE EXPLOSION OF STRAND GUN-COTTON, ARRANGED ACCORDING TO ASCENDING PRESSURES.

Under pressure of gas.	Tons per square inch.										
	1.5	2.5	8.0	8.0	12.0	12.3	18.0	20.0	45.0?	48.0?	50.0?
CO ₂ (vols.).....	26.49	29.62	30.95	31.00	32.23	32.70	33.63	33.01	34.70	34.77	36.18
CO “	36.66	35.03	32.27	32.76	30.65	31.36	31.20	30.32	28.60	28.66	27.57
H “	19.68	17.13	19.10	18.80	20.38	19.23	17.99	18.25	16.56	17.48	16.76
N “	16.85	18.18	17.20	16.90	16.43	16.25	16.23	16.60	16.83	16.05	16.15
CH ₄ “	0.32	0.04	0.48	0.54	0.31	0.46	0.95	1.82	3.31	3.04	3.34

II.—SIMILAR ANALYSES OF PELLET GUN-COTTON.

Under pressure of gas.	Tons per square inch.									
	1.0	1.5	6.5	11.0	14.0	15.0	17.0	17.0	25.0	30.0
CO ₂ (vols.).....	21.50	25.03	25.61	26.68	27.41	25.75	28.54	28.39	28.24	28.88
CO “ 	39.70	36.85	39.51	36.97	37.23	38.00	35.52	36.41	34.94	35.64
H “ 	22.83	21.00	18.80	19.59	19.37	19.71	18.47	19.64	20.30	20.50
N “ 	15.58	15.88	15.97	15.91	15.35	15.26	16.08	14.90	15.59	14.98
CH ₄ “ 	0.39	1.24	0.11	0.85	0.64	1.28	1.39	0.66	0.93	

III.—RESULTS OF THE ANALYSES OF STRAND GUN-COTTON WHEN FIRED IN A CLOSE VESSEL BY DETONATION.

	Pressure* per sq. inch.	
	1 ton.	3 tons.
CO ₂ (vols.).....	19.21	29.08
CO “	41.25	32.88
H “	23.07	20.14
N “	16.21	17.50
CH ₄ “	0.26	0.75

IV.—SIMILAR RESULTS FOR PELLET GUN-COTTON.

	Pressure per sq. inch.	
	3 tons.	10 tons.
CO ₂ (vols.).....	25.76	26.50
CO “	39.34	37.48
H “	18.71	20.97
N “	16.19	15.05
CH ₄ “	nil	nil

V.—RESULTS OF ANALYSES OF SATURATED PELLET GUN-COTTON FIRED IN A CLOSE VESSEL BY DETONATION.

	Pressure per sq. inch.			
	Under 10 tons.	10.5 tons.	16 tons.	16.5 tons.
CO ₂ (vols.).....	32.14	33.25	32.93	35.60
CO “	27.04	25.90	27.25	23.43
H “	26.80	26.53	25.76	24.22
N “	13.83	14.32	14.06	15.25
CH ₄ “	0.19	nil	nil	1.50

Such are the average analyses of the permanent gases generated by the decomposition of gun-cotton under the various conditions described, and it will be evident from these analyses that the volumes of the permanent gases may be expected to differ to some very appreciable extent, depending both upon the density under which it is exploded and also upon the mode of explosion. He has found it most convenient to explode the charges, the permanent gases from which were to be measured, under a pressure of about 10 tons per square inch (1524 atmospheres), and, under these circumstances, the average of several very accordant determinations gave, at 0° C. and 760 mm. of mercury, 689 cc. per gram of strand gun-cotton and 725 cc. per gram of pellet gun-cotton.

* The pressures given are those due to the gravimetric density of the charge.

At the temperature of explosion the whole of the water formed is in the gaseous state. It is therefore necessary, in order to obtain the total gaseous volume, to add to the above volumes of permanent gases the equivalent volume of aqueous vapor at the temperature and pressure stated. Now the quantity of water formed by the explosion of 129.6 grams of gun-cotton was found to be 16.985 grams; hence 1 gram of gun-cotton generated 0.1311 gram of water, equivalent to 162.6 cc. of aqueous vapor, and the total volume of gaseous matter at the temperature and pressure stated is for strand gun-cotton 852.2 cc. per gram, for pellet 887.6 cc.

The heat measured reached, with strand gun-cotton, 1068 gram-units water fluid, or 988 gram-units water gaseous, while with pellet gun-cotton these figures were 1037 or 957 gram-units respectively. Pellet gun-cotton made at Stowmarket generated 738 cc. of permanent gas and 994 units of heat per gram, while dinitro-cellulose containing 12.8 per cent. of nitrogen generated 748 cc. of gas and 977 units of heat, the water in both cases being fluid.

Gun-cotton, both pellet and strand, were detonated by means of mercuric fulminate with ease and certainty. The effect of employing this means of ignition in a close vessel is very striking, and the indications of intense heat are much more apparent than when the charge is fired in the ordinary way. This effect is probably partly due to an actual higher temperature, caused by the greater rapidity of combustion. This extreme heat is clearly indicated by the surfaces of the internal crusher gauges becoming covered with innumerable small cracks and by thin laminæ occasionally flaking off exposed surfaces; but perhaps the most striking proof of the violence of this detonation is shown by its action on a cast-iron shell fired as described; where no detonation takes place the shell is broken into fragments of various sizes, such as are familiar to all acquainted with the bursting of shell; but when detonation, with gun-cotton for example, takes place the whole shell is reduced to very minute fragments, and, what is more remarkable, two-thirds of the total weight are generally in the form of small peas and of the finest dust.

The ease with which gun-cotton can be detonated renders it unsuitable for use as a propulsive agent unless this property be in some way neutralized. He has, therefore, made but few

In the whole of these analyses the water formed by the explosion smelt strongly of ammonia.

The quantity of permanent gases measured, under the same conditions as in the case of gun-cotton, was found to be, for the earlier cordite, 655 vols.; for the present service cordite, 0.255 in. in diameter, 692 vols., and for that 0.048 in. in diameter, 698 vols. In the two latter samples the aqueous vapor was determined, and was found to amount to 20.257 grams for the 0.255-in. cordite and to 20.126 grams for the 0.048-in. cordite; or, stating the result per gram, these figures are respectively equivalent to 0.1563 gram or 194 cc. aqueous vapor, and to 0.1553 gram or 192.5 cc. per gram of cordite. Hence the total gaseous products generated by the explosion of cordite amount per gram to 886 cc. for the 0.255-in. cordite and to 890.5 cc. for the 0.048-in. cordite, the volumes being of course taken at 0° C. and 760 mm. atmospheric pressure.

The heat generated was found to be: for the earlier cordite, 1214 gram-units water fluid; for the service 0.255-in. cordite, 1284 gram-units water fluid or 1189 units water gaseous; for the service 0.048-in. cordite, 1272 units water fluid or 1178 units water gaseous.

From his very numerous experiments on erosion he arrives at the conclusion that the principal factors determining its amount are: (1) the actual temperature of the products of combustion, (2) the motion of these products. But little erosive effect is produced, even by the most erosive powders, in close vessels, or in those portions of the chambers of guns where the motion of the gas is feeble or *nil*; but the case is widely different where there is rapid motion of the gases at high densities. It is not difficult absolutely to retain without leakage the products of explosions at very high pressures, but if there be any appreciable escape before the gases are cooled they instantly cut a way for themselves with astonishing rapidity, totally destroying the surfaces over or through which they pass. Among all the explosives with which I have experimented I have found that where the heat developed is low the erosive effect is also low.

The most erosive of ordinary powders is the brown prismatic powder, which, on account of other properties, is used for the battering charges of heavy guns. The erosive effect of cordite, if considered in relation to the energy generated by the two

explosives, is very slightly greater than that of brown prismatic, but very much higher effects can, if it be so desired, be obtained with cordite, and, if the highest energy be demanded, the erosion will be proportionately greater. There is, however, one curious and satisfactory peculiarity connected with erosion by cordite. Erosion produced by the ordinary gunpowder has the most singular effect on the metal of the gun, eating out large holes and forming long rough grooves, resembling a ploughed field in miniature, and these grooves have, moreover, the unpleasant habit of being very apt to develop cracks; but with cordite the erosion is of a very different character. The eddy holes and long grooves are absent, and the erosion appears to consist in a simple washing away of the surface of the steel barrel.

Cordite does not detonate; at least, although he has made far more experiments on detonation with this explosive than with any other, he has never succeeded in detonating it. With an explosive like cordite, capable of developing enormous pressures, it is of course easy, if the cordite be finely comminuted, to develop very high tensions, but a high pressure does not necessarily imply detonation.

The rapidity with which cordite gases lose their temperature, and consequently their pressure, by communication of their heat to their surrounding envelope is very striking. Exploding a charge of about $1\frac{3}{4}$ lbs. of cordite in a close vessel at a tension of a little over 6 tons on the square inch, or say 1000 atmospheres, he has found that the pressure of 6 tons per square inch was again reached in 0.07 sec. after explosion, of 5 tons in 0.171 sec., of 4 tons in 0.731 sec., of 3 tons in 1.764 secs., of 2 tons in 3.523 secs., and of 1 ton in 7.08 secs. The loss of pressure after 1 ton per square inch was reached was of course slow, but the figures given are closely approximated to in two subsequent experiments. With ordinary gunpowder the reduction of pressure was very much slower, as was to be expected, on account of the charge being much larger; on account, also, of the temperature of explosion being much lower. These experiments are now being continued with larger charges and higher pressures.

It only remains to give particulars as to ballistics, that is as to the velocities and energies realisable by cordite in the bore of a gun, but these will be most conveniently given with similar details regarding other explosives.

The ballistite used has, like cordite, been changed in composition since the commencement of the experiments. The sample used for his earlier experiments was nearly exactly composed of 50 per cent. of dinitro-cellulose (collodion cotton) and 50 per cent. of nitro-glycerin. The cubes were coated with graphite, and the nitro-cellulose was wholly soluble in ether-alcohol. The second sample was nominally composed of 60 per cent. of nitro-cellulose and 40 per cent. of nitro-glycerin. The proximate analysis gave—

Nitro-glycerin	41.62
Nitro-cellulose	59.05

and, as before, the whole of the nitro-cellulose was soluble in ether-alcohol.

The earlier sample gave the following permanent gases under pressures of six and twelve tons per square inch respectively:

CO ₂	37.3	38.49
CO	27.8	28.35
H	19.1	19.83
N	15.8	13.32
CH ₄		traces

One gram of this ballistite gives rise to 610 cc. of permanent gases, and to 0.1588 gram of aqueous vapor corresponding to 197 cc. at 0° C. and 760 mm.

Hence the total volume of gas is 807 cc., and the heat generated by the explosion is 1.365 gram-units (water fluid), 1.269 gram-units (water gaseous).

Although he has not made nearly so many experiments on detonation with ballistite as with cordite, those he has made with the earlier samples (50 per cent. gun-cotton and 50 per cent. nitro-glycerin) neither detonated nor showed any tendency to, but a sample of ballistite consisting of 60 per cent. gun-cotton and 40 per cent. nitro-glycerin, in 0.2-in. cubes, detonated with great violence on two occasions, though he is unable, without further experience, to say whether this result was due to the change in the composition of the ballistite or to defective manufacture.

The erosive action of ballistite is, as might perhaps be anticipated from the higher heat developed, greater than with cordite,

but the remarks made with respect to the action of cordite apply also to ballistite.

The French B. N. powder consists of nitro-cellulose partially gelatinized and mixed with tannin, with barium and potassium nitrates. When exploded under a pressure of six tons per square inch the permanent gases were found to consist of—

CO ₂	28.1 vols.
CO	32.4 “
H	21.9 “
N	16.8 “
CH ₄	0.8 “

These permanent gases occupied at the usual temperature and pressure a volume of 616 cc.; the aqueous vapor formed occupied in addition 206 cc., so that the total gaseous volume was 822 cc. The heat generated was 1003 gram-units (water fluid), or 902 gram-units (water gaseous); the ballistics obtained with this powder are given along with those furnished by other explosives.

The results of the firing trials are exhibited by three plates. Fig. 1 shows the velocities of seven different explosives from the commencement of motion to the muzzle of the gun; the position of the points at which the velocity is determined is shown, and on the lowest and highest curves the observed velocities are marked where it is possible to do so without confusing the diagram. Lines are drawn to indicate the velocities that are obtained with the lengths of 40, 50, 75, and 100 calibers.

Fig. 2 shows the pressures by which the velocities of Fig. 1 were obtained. The areas of these curves represent the energies realized, and the lines intersecting the curves indicate the pressures at which the gases are discharged from the muzzle for lengths of 40, 50, 75, and 100 calibers respectively. The chamber pressures indicated by crusher gauges are also shown in Fig. 2, and it is to be observed that the two modes of determining the maximum pressure are in general in close accordance. It will further be observed that with the slow-burning powders the chronoscopic maximum pressures are somewhat, though not greatly higher than are those indicated by the crusher gauges. This observation is not new.* It was noted in the long series of

* Noble and Abel, *Phil. Trans.*, 165, 110.

experiments with black powders carried on by the Committee of Explosives. The result is widely different where an explosive powder or a quickly-burning powder, such as R. L. G., giving rise to wave pressure is employed; the crusher gauge in such cases* gives considerably and frequently very greatly higher pressures, and this peculiarity is illustrated in the curve from R. L. G. in Fig. 2.

The results given in Fig. 1 have to be considered in relation to the facts disclosed in Fig. 2. Thus it will be noted that the velocities and energies realized by 22 lbs. of 0.35-in. cordite and 20 lbs. of 0.3-in. cordite are practically the same, but reference to Fig. 2 shows that with the 0.3-in. cordite this velocity and energy has been obtained at the cost of nearly 30 per cent. higher maximum pressure. A similar remark may be made in regard to the French B. N. powder if compared with the ballistite. Its velocity and energy are obtained at a high cost of maximum pressure, and it is interesting to note how the velocity curve of B. N., which for the first four feet of motion shows a velocity higher than that of any other explosive, successively crosses other curves, and gives at the muzzle a velocity of 500 f. s. under that of cordite.

The velocities and energies at the principal points indicated in Figs. 1 and 2 are summarized in the annexed table, which shows for each nature of explosive the advantage in velocity and energy to be gained by a corresponding lengthening of the gun.

Fig. 3 offers an interesting illustration of a point elsewhere adverted to. Cordite and ballistite leave no deposit in the bore. Round 1 with R. L. G. was fired with a clean bore. The difference in velocity between round 1 with a clean bore and rounds 2 and 3 with powder deposit in the chase is very clearly marked, and it is shown that in this instance the effect of the foul bore is only distinctly evident when the length exceeds 40 calibers. From 40 calibers onwards the loss of velocity due to a bore encrusted with deposit is very distinctly shown.

* Compare Noble and Abel, loc. cit., p. 109.

TABLE SHOWING THE VELOCITIES AND ENERGIES REALIZED IN A 6" GUN WITH THE UNDERMENTIONED EXPLOSIVES.

Nature of explosive and weight of charge.	Length of bore, 40 calibers.		Length of bore, 50 calibers.		Length of bore, 75 calibers.		Length of bore, 100 calibers.	
	Veloc-ity.	Energy.	Veloc-ity.	Energy.	Veloc-ity.	Energy.	Veloc-ity.	Energy.
Cordite, 0.4" dia., 27.5 lbs.	2794	5413	2940	5994	3166	6950	3284	7478
Cordite, 0.35" dia., 22 lbs..	2444	4142	2583	4626	2798	5429	2915	5892
Cordite, 0.3" dia., 20 lbs...	2495	4316	2632	4804	2821	5518	2914	5888
Ballistite, 0.3" cubes, 20 lbs.	2416	4047	2537	4463	2713	5104	2806	5460
French B. N., 25 lbs.....	2422	4068	2530	4438	2700	5055	2786	5382
Amide Prismatic, 32 lbs...	2225	3433	2331	3768	2486	4285	2566	4566
R. L. G ₂ , 23 lbs.	1533	1630	1592	1757	1663	1929	1705	2016

Under the title, "Inspection of Cotton for Use in the Manufacture of Gun-cotton," Charles E. Munroe gives in *Jour. American Chemical Society*, **17**, 783-789; 1895, a detailed description of the tests which are applied, with data from the testing of several samples.

The erection of batteries of pneumatic guns along our coast makes the account of the "Pneumatic Torpedo Plant at Fort Winfield Scott," San Francisco, contributed to the *Mining and Scientific Press*, San Francisco, December 21, 1895, of interest, especially as it was constructed by Mr. Rix.

The Rix air compressors used for compressing the air are two in number and of the duplex pattern, each of about 400 H. P. capacity. The air is compressed in the first cylinders to 75 lbs. to the square inch, and is thence taken into a cooling tank containing about 1000 running feet of one-inch copper pipes, in which the air is cooled from the temperature of its discharge from initial cylinders, which is about 320 degrees, to the temperature of the water or thereabouts. It is delivered to the intermediate cylinder at about 65 degrees in temperature, and is there compressed in a single-acting ram to about 400 lbs pressure. The air is thence taken again into the intercooling chamber, through about 400 feet of copper pipe, and is cooled again to the temperature of the water, and is delivered to the high-pressure cylinder at the same temperature as to the intermediate cylinder.

In the third cylinder it is compressed to 2000 lbs., the air being delivered at a temperature of about 358 degrees. This is conducted to the third intercooler, where the temperature is reduced to about 65 degrees, and is thence conducted to the storage reservoir.

The engines which drive this compressing plant are of the Meyers cut-off style, and are extremely well balanced and well constructed; in fact, the cards and the results show that these compressors have a mechanical efficiency of about 85%, and throughout the system there is a saving of 36% over the work required to compress the air to 2000 lbs. adiabatically.

The amount of air delivered per hour, at 2000 lbs., is about 460 cubic feet, which is more than ample to keep the machines in operation; in fact, during the test one machine would have been sufficient to have maintained the number of shots.

One feature about this whole compressing plant is the facility with which the air is cooled. Each cylinder has a number of independent circulations, notably the high-pressure cylinders, where four circulations are introduced, each independent of the other, viz., a circulation for the head and valves, two circulations for the cylinders, and a circulation of water within the ram itself while it is in operation. This preserves the packing of the ram and at the same time contributes largely to the cooling of the air during compression.

During the operation of the plant the initial temperatures, that is the temperatures of the inlet for each air cylinder, did not exceed 70 degrees, while the temperature for the discharge of the air varied from 290 to 350 degrees.

The mechanical efficiency of the plant, that is the ratio of the indicated horse-power in the steam cylinders to the I. H. P. of the air cylinders, was $85\frac{1}{2}\%$, which is quite high, considering the fact that the machines were not designed for extra economical use, the idea being to provide for the Government something that could be operated easily and which was not easy to get out of repair.

After passing the intercoolers the air is delivered into 24 storage tanks, each 16 inches in diameter by 24 feet long, containing about 650 cubic feet.

These tanks are connected with the firing manifolds. These manifolds are of complex construction, designed so as to admit

the air to any or all of the guns and to admit the air to any or all of the storage tanks.

The air in the storage tanks is maintained at 2000 lbs., while the air delivered to the storage tanks of the guns is at 1000 lbs. pressure.

The guns themselves are very interesting in their character. They weigh about 70 tons each, above their foundations, are 50 feet long by 15 inches in bore. They can fire projectiles of any caliber from 8 to 15 inches, the difference in caliber between the full and the sub-caliber being made up by wood pistons in four sections which surround the projectile and which fly off immediately upon leaving the gun. These projectiles vary from 11 feet long and 15 inches in diameter for the full caliber to 8 feet long and 8 inches in diameter for the sub-caliber. The former carry 500 lbs. of dynamite explosive and the latter about 100 lbs.

The guns are easily traversed around the whole 360 degrees of circle, by an electric motor placed within one of the supports of the gun, and the connections of this motor are so arranged that it will also operate the mechanism for elevating and lowering the muzzle. The gun is ranged from 0 to 35 degrees, which is considered ample for all ordinary purposes. The greatest range obtained with the 8-inch projectile, carrying 100 lbs. of dynamite and which flies under a loss of pressure of about 100 lbs., was 5000 yards and slightly over. This may be considered the maximum flight for usual purposes. The 10-inch is proportionately less, and the 15-inch projectile, which carries 1000 lbs of dynamite and weighs 1100 lbs., has a range of from 2000 to 2500 yards. All of these projectiles may be thrown accurately, in fact there is no reason why, with the same pressure, the same amount of air wasted in the throwing of the projectiles, the same weight of projectile, and the same character of projectile, the atmospheric conditions being the same, it should not land practically in the same place. The results at Fort Point demonstrated this. The 8-inch projectiles were thrown from 5000 to 5070 yards, and were placed in the target, 70 yards in length by 30 yards in width, which far exceeded the Government requirements.

The material used in these projectiles is nitro-gelatine. The whole projectile is of an intricate mechanism, and has provisions made for exploding the charge either by direct impact, side impact, or by a delay of from one to three seconds. These pro-

jectiles are expensive, probably costing \$1000 each, and their capacity for destruction is fully proportional to their expense.

In the test at Fort Point the 15-inch projectile at 2000 yards threw up a column of water 350 to 400 feet high and 100 feet in diameter at the base, showing conclusively that it would be amply capable to destroy, within a range of 100 feet, the largest man-of-war.

The boilers which actuate this plant were manufactured by the Chandler & Taylor Co., of Indianapolis, are of about 500 H. P. capacity and are operated under forced draught, the idea being to keep the stacks low enough to be invisible from the bay. All of the fans which furnish the forced draught are each capable of furnishing 13,000 cubic feet of free air per minute to the grates. The boilers are fed by Deane duplex steam pumps, which are reinforced by sets of injectors.

The dynamo is operated by an Armington & Simms engine, of about 50 H. P. The dynamo is capable of furnishing 300 amperes, at 125 volts. The dynamo was manufactured by the Electrical Engineering Co., of this city, and is first-class in every respect. It also furnishes about 50 lights for the engine-room and offices during the evening.

The compressors and guns have exceeded all the requirements exacted by the Government. There was not one hitch or delay during the tests, excepting those caused by the weather, and judging from expressions, the entire Department feel that they have in these guns and the machinery to operate them a most efficient and satisfactory plant.

Shortly after noon on January 2, 1896, a series of explosions occurred at 309 N. Second Street, St. Louis, through which six lives were lost, a large number of persons injured, three buildings destroyed, and much other damage effected. From the account in the St. Louis papers, kindly supplied us by Prof. Sanger, it appears that a quantity of fireworks, of an estimated value of \$8000, were stored in the building and that they were in the custody of Mr. H. B. Grubbs, to whom they had been consigned by Detwiller & Street, of New York, with a factory at Greenfield, New Jersey. The explosions originated in a fire, the cause of which was undetermined, but which was attributed to rats, and there were three successive explosions. The effect of the

explosions was noticeably local and believed to be unlike the effect produced by a gunpowder explosion. For this reason the damage done was attributed to the explosion of "fire-crackers" of the variety known as "cannon crackers," "up-to-date crackers" or "dynamite crackers," and which were popularly supposed to contain dynamite. From the reports of the testimony before the coroner it appears that there were about 1000 boxes of Chinese and American cannon crackers in store, the largest of the latter being 15 inches long by 2 inches in diameter and having a 1-inch bore.

Five samples of fire-crackers taken from the wrecked building were submitted to Prof. Charles R. Sanger, of Washington University, for analysis, and he testified that the composition in the "up-to-date" fire-crackers consisted of 74 parts potassium chlorate, 24 parts sulphur and 2 parts charcoal or some other composition of carbon; that the charge in the large cracker was 150 grains and in the small one 10 to 12 grains; that the charges were confined by a tamping of clay; that the composition was fired by friction and by percussion; and that, in his opinion, if a considerable number of these fire-crackers were exploded they would cause others near them to explode.

From the *St. Louis Republic* of January 4, 1896, it appears that no law existed governing the storage of such explosives. This is evidently another example of spontaneous explosion due to contact of a chlorate with sulphur.

On December 6, 1893, an explosion of a cylinder of coal gas occurred on the wharf of the New Jersey Steamboat Co. at Albany, N. Y., by which two men were killed. Suits for damage were brought by the heirs of each of the deceased, the evidence being identical, but the plaintiff and the judge being different in each of the two cases. In the first case the plaintiff won, in the second case the plaintiff was non-suited and lost. Both cases were appealed, and in each the defendant won. Both cases were again appealed to the court of last resort, and through the courtesy of Dr. W. P. Mason we are in receipt of the plaintiff's brief in the case of Mary Egan *vs.* N. J. Steamboat Co. From this we learn that the cylinder was of steel; that it was seven inches in diameter by fifty-four to fifty-five inches long; that it was filled with illuminating gas made by mixing water gas and ordinary coal gas in such proportions as to produce a

mixture of nearly equal parts of hydrogen and carbon monoxide, with sufficient heavy hydrocarbons added to make it luminous; that the cylinder weighed about 100 lbs., and that the weight of the added gas was so small that, it is claimed, a laborer handling one of these cylinders could not tell, except by testing it, whether it was full or empty.

The counsel makes the points, among others, that the defendant was guilty of culpable negligence, under the common law, in directing the intestate to handle this cylinder, in its then condition, charged with gas to a high pressure, under the circumstances of the case; that he was guilty of violation of Sec. 4472 of Revised Statutes U. S., forbidding the transportation of nitroglycerin and like dangerous articles by passenger steamers; and that *illuminating gas is an explosive burning fluid* like the coal oil, camphene, benzine, and others cited in the statute. He cites the opinions of courts deciding that "gas" is an explosive. It is remarkable what confusion of thought regarding the properties of matter exists in the minds of otherwise intelligent men.

The exciting cause of this explosion has not been ascertained. It is stated that the explosion occurred just as the laborer, who carried the cylinder on his shoulder from the steamboat to the storehouse, was laying it down on the storehouse floor.

S. J. von Romocki presents in two stout volumes his "*Geschichte der Explosivstoffe*;"* volume I being devoted to the history of the chemistry of explosives, the technology of explosives, and to military and naval mining from their beginning up to the present century, while volume II treats of the history of smokeless powders up to the present time.

The extent of ground covered may be judged from the following titles of the chapters in volume I: War-fire up to the introduction of saltpeter; the first explosive; explosives in the Occident; the Fire-book of Marcus Graecus; the Fire-book in Konrad Kyesser's "*Bellifortis*"; the Fireworks-book and the explosives of the 15th century; Johannes de Fontana's Sketchbook; the beginning of sub-terra mines; the progress in the technology of explosives in the 16th century; the powder-ship before Antwerp in 1585; petards and marine mines; explosive missiles with

* Large 8vo. Vol. I., 394 pp.; Vol. II., 324 pp. Berlin: Robert Oppenheim (Gustav Schmidt), 1895.

flint and steel igniters; moveable and controlled torpedoes before La Rochelle in 1628; further inventions of Cornelius Drebbels; rocket and fish torpedoes. Copious extracts, in the original languages, are given from the Latin, Greek, Arabic, Chinese and other manuscripts and books. The chapters of volume II bear the following titles: Saltpeter powder with varying proportions of sulphur; chlorate powder; ammonium nitrate powder; picrate powder; xyloidine; the discovery of gun-cotton; gun-cotton up to its abandonment in Austria; nitro-cellulose from its revival in England to the discovery of the Vieille powder; the nitro-cellulose powders of the present time.

The work is a scholarly production, and bears evidence of the most painstaking research into the literature of the subjects treated of, while the numerous references are given with great detail and exactitude. The volumes are illustrated with 140 cuts, those in the first volume being of especial interest.

"Cellulose, an Outline of the Chemistry of the Structural Elements of Plants, by Cross and Bevan,"* is the most recent and most valuable work on this subject that has appeared, and it contains so much new and original matter that all who are engaged in manufactures in which cellulose in its various forms is employed, as for instance in the production of the explosive cellulose nitrates, should be familiar with its contents.

Apropos of the use of these nitrates in the manufacture of smokeless powders the authors remark: "These industries are in a highly developed condition, the manufacture being carried on with the greatest precision, on the basis of an extensive empirical knowledge of the properties of the products. It must be admitted, however, that, in the absence of any precise knowledge or even accepted theories of the constitution of the cellulose nitrates, there remains a vista of progress to be opened out by the solution or partial solution of this important problem."

"Coal Dust as an Explosive Agent, as shown by an Examination of the Camerton Explosion,"† by Donald M. D. Stuart, develops the theory that a colliery explosion, in which coal-dust is the principal agent, comprises numerous local explosions,

* London: Longmans, Green & Co., 1895. 8vo. 320 pp., 13 plates.

† New York: Spon & Chamberlain, 1894. Sm. 4to. 103 pp., 7 large plates.

separate in time and in space, at irregular intervals, where the normal supplies of atmospheric oxygen are greatly increased, and is caused by the explosive combustion of accumulations of hydrogen gas, derived from the coal-dust in the antecedent spaces, by a series of chemical actions of constant sequence, which produce heat for regeneration without auxiliary intervention, and are constantly reproduced along the path of the coal-dust under the conditions named.

An elaborate discussion of Mr. Stuart's theory and data will be found in *Trans. Am. Inst. Mining Eng.*, **24**, 905-917; 1895, to which Mr. Stuart replies in a very satisfactory manner in a paper read at the meeting, February, 1896, and to be published in volume 26.

Crosby, Lockwood & Son, London, announce the appearance of "Nitro-explosives," by P. Gerald Sanford. 270 pp. 1896; and Hirschfeld Bros., New York, announce "The Origin and Rationale of Colliery Explosions," by Donald M. D. Stuart.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

No. XXVIII.

By CHARLES E. MUNROE.

The Twentieth Annual Report of Her Majesty's Inspectors of Explosives very properly opens with a resumé of the results of the operation of the Explosives Act of 1875 under which the inspectors hold. The growth of the trade in explosives during this time has been remarkable. Not only has the number of factories increased in the United Kingdom from 55 to 134, but a large proportion of them have been enlarged, some of them having been more than doubled in size. This growth may to some extent be measured by the increase in the number of explosives which may be made in the several factories, or by the number of factories in which each kind of explosive can be made. Thus, while the number of factories in which gunpowder or nitrate mixtures may be made has remained stationary, the number for nitroglycerine compounds has risen from one to nine, and while dynamite was the only nitroglycerine compound produced in 1876, there are no less than twelve such compounds licensed now. The factories for gun-cotton compounds, which include nearly all the smokeless powders, have risen from nine to twenty-nine. The factories for fulminate of mercury have increased from two to six, and for the various kinds of ammunition to about the same extent, while the number of fireworks factories has doubled, notwithstanding the large importations

* As it is proposed to continue these notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications or trade circulars. Address, Columbian University, Washington, D. C.

of Chinese and other oriental fireworks during this interval. The number of magazines has increased from 199 to 288. The comparison for employees is made only for ten years, the number having increased from 7484 in 1885, to 10,023 in 1895. "The number of deaths from accidents by fire or explosion in manufacture was ten only, which, although above the average for the past ten years, marks an extraordinary and most satisfactory contrast with the figures which obtained before the Act came into operation. We repeat that it should also be remembered that not only has the actual number of factories largely increased, but also, in many cases, the amount of output of an individual factory, and consequently the number of hands employed and the resulting chances of accident. Moreover, the risks attending the manufacture of wholly new explosives, to which a large proportion of the new factories are devoted, are less well known than those connected with the more familiar explosives, and, therefore, are not so easy to provide against." The total number of accidents from all causes (excluding non-fatal mining accidents with gunpowder) were 152, causing 40 deaths and injuring 167 persons, while for 1894 the accidents were 102, with 28 killed and 91 injured, and the average for ten years is 132 accidents, with 37 killed and 114.3 injured. The increase in the number reported for 1895 is in a measure due to increased facilities for collecting reports. Only one-fifth of the accidents causing death or personal injury occurred under conditions controlled by the Explosives Act, viz. during manufacture, keeping and conveyance.

It is to be regretted that these reports do not give the amount of the various explosives produced and consumed in Great Britain, as this would be a valuable criterion by which to test the working of the Act.

The complaints that the restrictions imposed by the Act fettered competition with foreign manufacturers, which were freely made in anticipation of the passage of the Act, and which were common in the early days of its administration, have of late years become extremely rare. Other countries have since enacted laws or applied regulations based in no small degree on these, and, as a general rule, of increased stringency. Of these is the Belgian law of October 8, 1894, which appeared in the *Moniteur Belge* of November 8, 1894, and of which

the commissioners themselves say, in submitting the code, "This code is exceedingly severe, but it is rendered imperative by the exigencies of public security," and the German law, which, in many of its regulations, such as the making of cartridges,* goes far beyond what is required in England. The French Committee on Explosive Substances said several years ago of the English Explosives Act: "It appears to the Committee that these wise measures ought to be initiated in France, regard being had to the differences in our institutions and our legislation."

In the operation of the Act during 1895 the following have been added to its list of authorized explosives: Dahmenite A (nitrate of ammonium, naphthalene and bichromate of potassium; the latter not to exceed 2.5 per cent.); Electronite (Nos. 1 and 2) (No. 1 consisting of blasting amberite with carbonate of calcium, and No. 2 of nitrates of ammonium and potassium with wood meal); Emerald Powder (Cooppal's powder colored with the oxalate variety of malachite green); Faversham Powder (nitrate of ammonium with di-nitro-benzol, di-nitro-naphthalene, tri-nitro-naphthalene, chloride of sodium and chloride of ammonium or either of them); Pigou's Military Smokeless Powder (gun-cotton thoroughly purified and gelatinized); Pigou's Sporting Smokeless Powder (nitro-cotton, nitrate of barium and starch colored with indulin); Roburite No. 3 (nitrate of ammonium, di-nitro-benzol and chloro-naphthalene); Rosslyn Smokeless Powder No. 1 (nitro-cotton, nitrates of barium and potassium, or either of them, paraffin or vaseline, and starch), and Rosslyn Blastite (the same ingredients as the preceding, but in a different form), while gunpowder cartridges enclosing sealed tubes containing liquid ammonia have been treated as gunpowder cartridges pure and simple.

Although all nitro-cotton is now admitted to be explosive, and collodion cotton (except when in solution in alcohol and ether, or wet or saturated with methylated spirits and enclosed in air-tight cases) appears on the authorized list; the particular form of collodion cotton used in the manufacture of xylonite and kindred articles may be used under the following easy conditions:

"If the collodion cotton contain not more than 11.11 per cent. nitrogen, then (a) if the quantity do not exceed 1000 pounds, no distances need be assigned, but the building to be constructed

* Proc. U. S. Nav. Inst. **22**, 601, 1896.

so far as practicable of uninflamable material, and must be screened from other buildings by a substantial fire-proof screen of such material, construction and dimensions as shall satisfy a Government Inspector; provided that the wall of the building itself, or the wall of any adjoining building, or both walls, may, with the approval of a Government Inspector, be deemed to be such screen; and (b) if the quantity exceed 1000 pounds, the distances to be observed from other buildings and works may be half those laid down for the corresponding quantity of gun-cotton, subject to such further reduction, if any, on account of the nature of the ground, intervening mounds, or screens, as in the judgment of a Government Inspector may be properly admitted."

A summary of the reports received on the use of the jelly-bag system of mixing dry cap composition are all in its favor, only four accidents, which were harmless, having occurred with it since 1891, while one company reports having mixed 60 tons of the composition by this means, since 1891, without accident.

Permission to send safety fuze by post was refused on the ground that it might be equally well asked for percussion caps, amorces (properly packed), time fuzes and the like, all of which are classed as explosives, and that it was best to prohibit *all* explosives being sent by mail.

The importation of foreign nitroglycerine compounds for 1895 was—

Blasting gelatine	15,650 pounds.	
Carbonite	223,000	"
Dynamite	56,000	"
Gelatine dynamite	493,920	"
Matagnite gelatine	91,500	"
<hr/>		
Total	880,070	"

This is an increase on the amount (539,802 pounds) imported in 1894, though it does not reach the average of former years. The dynamite rose from 23,000 pounds in 1894, and the matagnite gelatine has more than doubled. The number of detonators imported in 1895 was 6,981,000, as against 9,765,400 in 1894; while 496,000 pounds (248 tons) of fireworks were imported,

against 290 tons in 1894. A considerable portion of these importations is for re-shipment abroad.

The chemist, Dr. Dupré, reports the examination of 302 different samples, of which all but three (and all of these were fireworks) passed.

The results of the test of one sample of gun-cotton are of special interest. This sample had been manufactured at a time when the pulping of nitrated cotton had not yet been adopted, and must, therefore, have been something like 25 years old. It was contained in a half-pound square tin canister.

The canister was in several places perforated by corrosion, and all the gun-cotton in contact with the metal was stained dark reddish brown. It gave the following results on examination:

Nitro-cellulose, insoluble.....	95.46, heat test, one hour.
“ soluble	3.50, nitrogen, 13.2 per cent.
Mineral matter	1.04
<hr/>	
100.00	

The mineral matter was chiefly oxide of iron and sulphate of calcium. There was no carbonate of calcium or sodium. The analysis shows that this sample of gun-cotton, probably over 25 years old, is of remarkably good character, and that it has apparently improved, rather than otherwise, as regards the heat test.

Among the alterations permitted in explosives already licensed is the addition of mineral jelly to ballistite.

The *heat test* for gun-cotton and non-gelatinized gun-cotton preparations has been made more stringent by raising the temperature to be employed from 150° to 170° F., the time (10 minutes) remaining as before.

The temperature for the heat test to be applied to all horny or semi-horny explosives consisting mainly of gelatinized gun-cotton (such as Walsrode powder), or gun-cotton and nitroglycerine (such as cordite and ballistite), has been raised to 180° F.

Among the Accidents we note one occurring at Hayle on November 5, during the manufacture of cordite. A cylinder full of the paste had been placed in the squirting press and the pressure just applied, when the cylinder burst and a stream of fire was seen to issue from underneath the press. Through this three of

the six persons present were slightly burned, while 40 pounds of cordite present in the building were set on fire, resulting in the complete destruction of the building. The pieces of the cylinder were not projected with any great violence, and all danger from them could have been prevented by a rope mantlet. The accident is believed to have been due to the heat developed by the too sudden compression of the air in the interstices of the paste, and may be averted by some arrangement for controlling the movement of the plunger.

A similar accident occurred at Waltham Abbey, April 22. The cylinder contained about 30 pounds of cordite paste. About one ounce appears to have exploded, breaking the cylinder in four pieces, and projecting two of them with some violence. The bulk of the paste fell out of the broken cylinder intact, instead of being scattered about, as in the Hayle explosion.

The various explosive accidents reported from the Eley Bros. works, where the wet process for mixing cap composition still prevails, indicates that this method is more liable than the dry process to produce a dangerously sensitive cap. There is undoubtedly a tendency in all chlorate mixtures which have been wet to form minute crystals on the surface and become unduly sensitive in consequence. The wet process may also under certain conditions leave a thin smear of composition on the walls of the cap. Yet there is no doubt that the wet process is free from certain manufacturing risks which it is impossible wholly to eliminate from the dry process.

Among the descriptions of "Foreign Explosions" we especially note those at Leeuwfontein, South Africa, November 28; Butte, Montana, January 15; Pinole, California, May 21; Parkersburg, West Virginia, June 2; and Keeken, Germany, March 19, for their magnitude, the last named being the largest explosion of explosives in transit on record, except that at Santander, November, 1893. Of additional interest is the fact that the explosives at Keeken were frozen at the time of explosion. As much data as possible is given in each case by which to determine the radius of destructive effect.

Several accidents from frozen nitroglycerine explosives are elsewhere recorded in this report.

Among the "Miscellaneous Accidents" are explosions from lignozote (ordinary japan dissolved in benzoline); ether in transit,

by which a freight train was destroyed; and a chlorate of potash lozenge which was rubbed against the igniting surface of a safety-match box in the pocket of a stock broker.

After the usual good-sized list of "Outrages" and "Petroleum Accidents" comes the record of "Experiments," which were devoted to testing the degree of inflammability of magazine clothing when exposed to burning cordite or other nitro-compounds. Many materials were tried, among them lasting cloth jackets and stout woollen cloth trousers, as supplied by the Government, but the most satisfactory in every respect is "white duck" treated with the following solution:

Ammonium sulphate	8 parts.
Ammonium carbonate	2½ "
Boric acid	3 "
Borax	1¾ "
Water	200 "

Dissolve, then add two parts starch, stir well and boil. The fabric should be dry before steeping in this solution.

This most satisfactory report closes with a description of the blowing up of the "Talcen Mawr," a rock which had been immortalized by Welsh bards, and which was estimated to contain from 125,000 to 200,000 tons of matter.

Oscar Guttman contributes to the *Jour. Soc. Chem. Ind.* **16**, 283-293; 1897, an article entitled "The Chemical Stability of Nitro-Compound Explosives," which discusses the "heat test" as now prescribed, and offers a new one.

The chief "nitro-compound" explosives, nitroglycerine, nitro-cellulose or mixtures of these, nitro-benzene, nitro-toluene, picric acid, picrates and the like, are manufactured now-a-days so well that the only possible cause of decomposition is through the action of heat; though sometimes substances are added to them, either to neutralize any free acid present, or to modify the explosive effect, or sometimes they are subjected to mechanical treatment which affects their stability.

Various methods have been proposed to ascertain whether or not an explosive is liable to decompose at the temperatures to which it may be exposed in ordinary storage and use; all of which are based on the detection and the presence of nitrogen

peroxide if it be developed in the explosive. Hess passes the vapors from the heated explosive into a solution of potassium iodide. Some subject the sample to 100° - 135° C. for a day or a week, the absence of red fumes being taken as an evidence of stability. Abel's * heat test, using potassium-iodide-starch paper as an indicator, as modified by Dupré,† is used in Great Britain, while in Germany zinc-iodide-starch paper is used.

With proper attention, there is now no difficulty in producing, by Abel's process of pulping and poaching, gun-cotton of sufficiently high stability to pass the English heat test. The practice of adding carbonate of soda, lime, magnesia and the like, is being gradually dispensed with. Guttman believes himself to have been the first to point out that such addition is not only unnecessary, but a deception, for if real decomposition be going on in an explosive the small quantity of neutralizer added will soon be exhausted, while some of these added bodies have themselves a tendency to decompose some nitro-compounds. That a properly purified explosive will keep practically forever under ordinary circumstances of storage is exemplified by the original sample of nitroglycerine made by Sobrero in 1874, and now stored at the Nobel factory in Avigliana. That the different substances used as neutralizers act differently was shown by Dupré, who found that while practically no effect on the "heat test" resulted from adding calcium or magnesium carbonate to gelatine dynamite, sodium carbonate tended to increase the duration of the test in bad samples and decrease it in good ones. In the bad sample it neutralized the acid already present; in the good sample it tended to decompose it. Guttman found that ammonium carbonate added to blasting gelatine caused decomposition to such a degree that the gun-cotton partly disappeared and the nitroglycerine sweated out from the cases so that the walls and floor of the magazine were wet with it. The ammonia, which is easily liberated from ammonium carbonate, acts on nitroglycerine, but more readily on gun-cotton.

The nitro-substitution compounds (picric acid, etc.) are easily purified by washing, recrystallization and washing with neutralizers, and are perfectly stable when free from acids.

* Proc. U. S. Nav. Inst. 5, 11; 1879.

† Proc. U. S. Nav. Inst. 13, 231; 1884.

Being an oily liquid, nitroglycerine is more difficult to purify, but by the use of compressed air it can be cleansed; sodium carbonate or soda in powder being added to the wash-water to neutralize the bulk of the acid, and the remaining traces being taken out by repeated washings with hot or cold water or very weak soda solution. Besides mixing the nitroglycerine more thoroughly with washing liquids, the compressed air serves to oxidize the lower "nitro-compound" generally present in impure nitroglycerine. Among obscure causes of persistent acidity in nitroglycerine Guttman found the presence of the spongy lead sulphate, formed in the lead nitrating apparatus, to be one. Being porous, and being especially formed on the line of contact between the air and surface, it absorbs and retains the nitrous impurities, and being detached it falls into and passes off with the nitroglycerine. A minute quantity of this in the sample tested will seriously affect the heat test. Cleansing the "nitrator" corrects this. Another source of error was found due to the method of adding the soda in washing the nitroglycerine. When this is added in powder, instead of in solution, soda mud is thrown down. If some of this mud be placed on litmus paper it gives a distinct alkaline reaction, but if a drop of nitroglycerine be put on top of it and allowed to remain for a while, there will be an acid reaction at the line of contact between the nitroglycerine and the soda mud showing decomposition.

It is not to be assumed that because each of two "nitro-compounds" is stable under the heat test a mixture of them will have equal stability. Blasting gelatine is made by dissolving soluble gun-cotton in nitroglycerine by gentle heating. As some "nitro-compounds" develop nitrogen peroxide at temperatures lower than that of the official "heat test," the stability of the finished product will depend much upon the temperature at which the blasting gelatine is made and the mechanical treatment that it has undergone. The same is true with mixtures of picrates, solutions of gun-cotton in nitro-benzine, and molten masses of "nitro-compounds" of low melting points. In making smokeless powders the paste is made by prolonged treatment in kneading machines, and is frequently rolled into sheets in steam-heated rolls which reduce the duration of the heat test, since treatment at elevated temperatures produces local develop-

ment of nitrogen peroxide, which then develops progressively. In making blasting gelatine the nitrogen contents or solubility of the gun-cotton in nitroglycerine are not reliable criterions of the ability of the gun-cotton to retain nitroglycerine, as heretofore supposed.

Dynamite may be mechanically unstable through exudation. This depends on the absorptive capacity of the kieselguhr, and the temperature to which the dynamite is subjected. When too low the nitroglycerine freezes, contracts nearly one-tenth its volume, and leaves the outer layer of the absorbent, so that when thawed again it may not distribute itself uniformly through the absorbent. When too high the nitroglycerine expands, and, if the guhr was originally super-saturated, oozes out. Water also, by osmotic action, displaces the nitroglycerine. The possible effect of the heat test on explosives increases with the number of their constituents. Twelve years ago it was found that a good dynamite could not be made with a perfectly good nitroglycerine and an apparently excellent kieselguhr. Examination of the latter showed the presence of considerable amounts of aluminum sulphate, and tests proved that a small quantity of this salt decomposed nitroglycerine.

Several years ago great difficulty was found in transporting gelignite to Australia by sailing ships. It would pass the heat test in England, but fail in Australia and be condemned and destroyed. The cause was found in the wood pulp used in its manufacture. It was essential that it should be dry, and in drying it a part of it was charred, developing acetic acid and methyl alcohol. Guttman shows that a very small quantity of acetic acid lowers the heat test, though it does not affect the stability of the explosive. When sodium carbonate is present, the methyl alcohol, as a solvent of the "nitro-compounds," accelerates their decomposition.

The smokeless powders gave the Home Office authorities much trouble, which was overcome by requiring for the Schultze class that they be dried in an oven at 120° F. and exposed to the air for two hours before trial by the heat test; and for the cordite class that they be ground in a pug-mill, sifted through a set of thin sieves, and the material retained by the second sieve used for the test.

In September, 1895, Hermann Güttler pointed out that while

he could get a heat test reaction, with iodide paper, from Plastomentite, he could either get none, or only after hours of heating, from Walsrode powder, and that if he put a developed iodide paper in the tube with Walsrode powder, the brown line disappeared almost immediately. Guttman found, as was to be expected, that this brown line disappeared if the paper was heated for five minutes in an empty test-tube at 180° F., as such discharge of the color is a long and well-known lecture experiment. The German zinc iodide paper proved more sensitive than the English paper. He found that old Walsrode powder gave a much quicker heat reaction than a recently prepared one, and that a large variety of substances are contained in the different smokeless powders which, in his opinion, will stultify the heat test. Foremost among these are acetic ether, acetone and oils, but vaseline, aniline and other substances affect it also. The amount of solvent left in smokeless powder is variable. The greater the density the more difficult it is to drive the solvent off, so that some powders retain as much as one per cent., while others retain but a fraction of a per cent. Though the latter amount may not be apparent to the smell, yet, when the powder is ground and heated in the tube, its presence will be made evident, and if this ingredient be of the class which acts upon iodine, it will tend to make the line on the test paper disappear as the nitrogen oxide given off tends to make it appear. Consequently a powder may be in a state of decomposition and yet the solvent present may prevent the formation of the "brown line" until either the development of the nitrogen oxide has become very great, or a part of the solvent has been driven out by leakages about the stopper or glass rod. This action of acetone and castor oil Guttman believes explains why he was unable to get a "heat test" reaction with Maxim's powder, even after a two hours' exposure at 90° C., as both these substances were present in the powder.

Besides this, iodide-starch papers made by different chemists gave different results with the same powder. A powder ground in the evening gave a longer "heat test" when tested at once than when tested next morning. Sometimes a powder that was exposed for many months gave a better "heat test" than a freshly prepared one. Coarsely ground powders gave worse "heat tests" than finely ground ones. The mill used for grind-

ing the powders chips the powder, and, though only those grains that are retained by a certain sieve are used for the test, yet there are great differences of size whereby different quantities of the solvent may be given off. From this Guttman concludes that the iodide heat test, as at present prescribed, is absolutely inapplicable for most of the modern smokeless powders and for some blasting explosives.

As manufacturers may suffer great pecuniary loss through having their products condemned by an unsuitable method of testing, Guttman sought for a more reliable method, and looking over the various reagents proposed during the last forty years for the detection of small quantities of nitrogen peroxide he tried the following: Griess', a mixture of sulphanilic acid and naphthylamine in acetic acid; Plugge's, mercuric nitrate and carbolic acid; Jorrissen's fuchsine dissolved in glacial acetic acid; Vogel's rosaniline; Medola's para-amido-benzeneazodimethylaniline; Curtman's antipyrine; Kopp's diphenylamine; Frankland's sulphanilic acid and phenol; Griess' *m*-phenylene diamine hydrochloride.

Of these, for reasons given at length, Guttman selected diphenylamine, and he makes the reagent and test as follows: Place $\frac{1}{10}$ gram of diphenylamine crystals in a wide-neck flask with a ground glass stopper, add 50 cc. of dilute H_2SO_4 (10 cc. H_2SO_4 : 40 cc. H_2O) and place the flask in a water-bath at 50° to 55° C. At this temperature the diphenylamine will melt and at once dissolve in the sulphuric acid, when the flask should be removed from the bath, well shaken and allowed to cool. After cooling, add 50 cc. of Price's double-distilled glycerine, shake well, and keep in the dark. This solution has a strength of about 1 in 1000 by volume.

In making the test 1.5 grams of the explosive, prepared as prescribed in the English tests, is placed in the test-tube heretofore used. Strips of well-washed filter paper, or of any good chemical filter paper, 25 mm. long and 10 mm. wide, are attached to the hooked glass rod as usual and moistened, by applying with a clean glass rod a drop of the diphenylamine solution to the upper corners of the filter paper, so that when the two drops run together about a quarter of the filter paper is moistened. This is now put in the test-tube, which is *now* put in the water-bath, which has been heated to 70° C. The heat test reaction

should not show in less time than fifteen minutes. It will begin with a greenish-yellow color on the moist part of the paper, and from this moment the paper should be carefully watched. After one or two minutes more a dark blue line will suddenly appear on the dividing line between the wet and dry part of the paper, and this is the point that should be taken.

The blue mark appears promptly within a few seconds, while with the iodide paper it takes sometimes as much as two minutes to obtain a well-defined brown line, and even then careful operators often have disputes as to whether the brown line exists or not. The blue mark is not as readily visible by night as by day, but it is still sufficiently clear to be detected. It is better to look at the paper with the light falling on it rather than passing through it from behind. In case of doubt a screen of filter paper behind the tube will make the blue line more readily visible. The incandescent gaslight is the best for observing with; a screen of thin light blue paper being required when the electric or ordinary gaslight is used.

It is essential that the explosive shall contain the least possible moisture, as otherwise the paper will soon become thoroughly wet, when no test can be made. The drying of explosives at temperatures above 40° C. is inadvisable, as at 45° to 50° C. traces of nitrogen peroxide are often developed which would vitiate the test. The present Home Office regulation for drying gun-cotton in an open water-oven at 120° F. is satisfactory, though it might be advisable to dry for one hour instead of fifteen minutes, but at 40° C. only. Smokeless powders should not, as a rule, be dried, as some of the ingredients are, to an extent, volatile at 40° C., while usually they do not contain an appreciable amount of moisture.

Guttmann believes that the coefficient of transmission of heat should not be neglected in these tests, and his experimental data justify his view. In addition he experimentally investigated the relation between the temperature to which a sample is exposed and the time within which the diphenylamine reaction shows itself, and exhibits the results for five bodies in a graphic manner, giving also the formulas by which such curves may be charted. From these he concludes that it will scarcely be sufficient to say that an explosive must withstand a certain temperature for a certain number of minutes to be reasonably safe, for it is pos-

sible to conceive a case where an explosive has a constant approaching zero, and whose decomposition at increased temperatures may require wide intervals of time; while, on the other hand, one may have to wait a rather long time to start decomposition, and yet when once started it may develop rapidly.

Referring to his results, Guttman says: "Considering that . . . it takes $8\frac{1}{2}$ minutes to heat the contents of a test-tube to 70° C., it may cause surprise that the constant of some powders on the diagram is 5 minutes, and that of gun-cotton 3 minutes only; but this is due to the fact that with them decomposition starts at a lower temperature than 80° C. The heat test value of an explosive will, therefore, be the inferior the more its constant is below the time required for obtaining equilibrium between the outer and inner temperatures of the test-tube, and it will be advisable to fix a minimum limit for the constant of say 5 minutes."

The author does not claim that his method meets all objections to the "heat test." There are still vagaries encountered in its use, and it will still be empirical, but the beneficial effects thus far resulting from the "heat test" prove it to be a necessity.

The paper aroused an extended discussion in which many authorities took part, and which is as valuable as the paper itself. These speakers, as a rule, had not encountered the difficulties in the use of the iodide starch paper that Guttman had, and Dr. Dupré did not express himself as ready to abandon it for Guttman's. Mr. Otto Hehner pointed out that while the iodide-starch was a reagent for nitrous compounds, the diphenylamine was a reagent for nitrites or nitrates, the latter of which cannot be detected by the iodide test, and it was therefore obvious that in many cases the two tests could not give the same results because they did not apply to the same thing.

In the *Jour. Am. Chem. Soc.* **19**, 156-170; 1897, E. C. Woodruff gives the results of his study of the "Color Reactions of Nitric and Chloric Acids with Certain Aromatic Bodies," in which he sought to find some new practical tests for nitric and chloric acids, more especially such as would differentiate the two, both in mixtures and separately. The latter object was repeatedly attained. The former was more difficult, because, in general, chloric acid produces a darker color reaction than nitric, in some

few cases sufficiently so as to indicate chlorates in the presence of nitrates; in most cases enough darker to completely mask the nitrate effect; while in some cases the effects were indistinguishable. Still, two methods are given whereby the nitrate effect can be made to predominate, and one that, properly manipulated, accomplishes the desired result very well. The reagent used is dimethylaniline with paratoluidine and sulphuric acid. It gives a colorless solution that keeps well and is an absolute test for nitrates.

The author experimented with a large number of phenols, cresols, oxyacids, amines and so on, and gives his results. Speaking of diphenylamine, he says that "four per cent. gave a light green solution which gradually darkened. This makes a fairly delicate test for nitrates, but there are several serious faults in its workings. First, it gives a rather poorly keeping solution. Second, it will not bear dilution or neutralization. . . . Third, it must be kept cool, as heat alone, even the heat generated by adding a drop of distilled water to two or three of the solution, may give the color supposedly due to a nitrate. Heating changes it first to green, then to a blue, and finally to dense black flakes in a colorless liquid in which water no longer produces a muddy brown precipitate as before."

Under the title "Some Recent Improvements in Smokeless Powder Compounds and in Processes of Manufacture," *Jour. Soc. Chem. Ind.* **16**, 495-499; 1897, Hudson Maxim gives a general review of the composition and properties of smokeless powders, and, speaking of the Maxim-Schüpphaus powders, says a method patented by us for producing a smokeless powder of this character is substantially as follows: Trinitro-cellulose is made into papers or a thin pulp board, which is subjected to a bath made of soluble pyroxyline dissolved in a solvent which is not a solvent of the trinitro-cellulose. In other words, the gun-cotton paper is sized in a collodion bath, which bath may or may not contain nitroglycerine; the excess of the bath being removed, sheets of the material are placed upon one another and pressed together, whereby a body of any desired thickness is built up. The mass is then placed in a suitable die or mold and multi-perforated in a manner explained further on. The hardness and density of the product may be varied within wide

limits by varying the consistency of the bath or the amount of size left in the paper, and also by varying the compression. The material may then be cut into strips approximating in length the powder chamber of the gun, or any length desired. Before being perforated a sheet of unnitrated paper may be affixed to two surfaces of the body, whereby they will be to a great extent protected from ignition during the early stages of combustion in the gun, thus causing a greater degree of combustion to take place within the perforations. Or, the body of material may be multi-perforated and dried, and then coated with any suitable substance which will delay ignition of the surface.

The old black and brown powders being but compressed mechanical mixtures, were unsuited to that special form of grain consistent with the production of the highest ballistic results. With the introduction of smokeless powders, made of a dense and tenacious colloid of gun-cotton, or of gun-cotton and nitroglycerine, it became possible, by a special system of multi-perforations, to produce a grain which will burn in the desired manner, although this result has not been easy of attainment. Trinitro-cellulose requires a large quantity of solvent, not only to dissolve it, but even to render it plastic, and rods or grains formed of it are exceedingly difficult to dry without warping and cracking to pieces, and it is difficult to make it take and retain the exact shape of the forming die. Consequently, unless a very large percentage of nitroglycerine be employed, a composition must be produced which allows working in a much drier state than ever heretofore attempted, in order that the plastic mass shall retain the shape given it by the die in all its geometric details. All this calls for special tools, special processes, and a special compound.

Two smokeless powder compounds are employed by him; one consisting of a compound of nitroglycerine and mixed gun-cottons, the other of mixed gun-cottons without nitroglycerine. The first is made by mixing together in a kneading machine, at a temperature of about 120° F., 80 pounds of trinitro-cellulose of about 13.3 per cent. nitrogen, with 8 pounds of gelatine-pyroxylene of 12 per cent. nitrogen (and soluble in nitroglycerine below 100° F.), 12 pounds of nitroglycerine and 35 pounds of pure anhydrous acetone, adding thereto 1 pound of pure urea dissolved in pure methyl alcohol. The mixture is

worked in the kneading machine for about an hour at a temperature of about 120° F., heated by means of a water-bath. The mealy mass is then passed between cold rolls and formed into rough sheets, which are then converted into smooth sheets by passing between slightly warmed rolls. The proper consistency for the mass is easily recognized by the experienced workman by the sense of touch, but the amount of solvent retained may also be easily ascertained by weighing from time to time. Only from 15 to 20 per cent. of solvent should be retained when the compound is ready for stuffing or molding into grains.

The smooth sheets are compactly wound about one another to form a roll of the diameter of the press cylinder, the ends preferably being trimmed. The press is kept warm by means of a water-jacket having a temperature of about 120° F. The press being filled, the cylinder is preferably exhausted of the air within the spaces unfilled by the powder, and the mass pressed hard against the head to solidify it. The forming die is now affixed and the compound forced through it at a pressure of from 3000 to 4000 pounds per square inch, emerging in the shape of multi-perforated cylinders. The smaller the grain the softer should the material be and the higher the pressure required to force it out. The rods are cut into grains about 3 diameters long, placed on shelves in a drying-room, and when partly dried finished in a vacuum.

In the other composition 80 parts of trinitro-cellulose, 19½ parts of gelatin-pyroxylene and ½ per cent. of urea are used. Owing to the absence of nitroglycerine, which facilitates the molding operations, slightly more solvent is left in the material before pressing. It is impossible to evaporate the last trace of solvent from either of the compounds, "but as the quantity remains forever constant, and never escapes, it does no harm."

The peculiar influence of urea is well illustrated by its use in the manufacture of celluloid, such as photographic films, which, in case they are cut from a block of compressed material, and not made by flowing a comparatively thin solution on glass plates, or by an equivalent method, could not be produced without the use of this substance, as the temperature to which it is necessary to subject the material causes such slight decomposition as to discolor the product. Urea counteracts this by neutralizing the nitrous acid as fast as it is formed. Urea has the further

advantage that it is decomposed by nitrous acid into carbon dioxide, water and nitrogen, leaving no solid product behind, while it is not an active alkali and its presence has no effect whatever upon the nitro-compounds with which it is combined.

When soluble pyroxyline is combined with trinitro-cellulose in suitable proportion it has the peculiar effect of rendering the compound plastic and enabling it to be molded with very much less solvent under the influence of an elevated temperature. This effect resembles that produced by camphor combined with celluloid pyroxylin. It furthermore renders the final product more tenacious and less liable to crack.

This is followed by illustrations, with descriptions, of a large number of different forms of perforated grains. No novelty seems to be claimed for them except "a rod or strip of powder having transverse perforations as a new article of manufacture."

In the discussion Mr. McNab observed that Mr. Maxwell Lyte had, about 1868-69, introduced a smokeless powder in France which closely resembled the form described by Mr. Maxim. While Dr. Dupré said that the use of urea was a practice which he had always set his face against, as it was equivalent to, say, adding boric acid to milk to mask a want of cleanliness or of honesty in the milk trade. If a powder were well made it ought to stand without urea or any other masking body. It appeared to him that Mr. Maxim wanted to produce a powder that burnt more rapidly as combustion proceeded. The greater the pressure the more rapid was the combustion, and no peculiar shape of the pellet was needed to ensure this.

In the *Jour. Am. Chem. Soc.* **19**, 388-389; 1897, C. C. Parsons describes a "Method of Drying Sensitive Organic Substances," which he has successfully employed in drying wood-paper pulp in some investigations in nitrating it for a smokeless powder. The process consists in completely immersing a weighed portion of the substance to be dried in about six times its weight of oil in an evaporating dish. The dish containing the oil is placed in a drying closet kept at 240° until the oil has attained this temperature, when it should be weighed and the weighed substance is then immersed in it. There is a slight effervescence during this operation, which is the greater the larger the amount of moisture present. The whole is returned to the closet for a

few minutes and then weighed again, and this is repeated to constant weight. The loss is moisture. The oil prescribed is what is commercially called a straight paraffin oil, free from animal or vegetable oils or fats or foreign mineral substances, perfectly neutral, 0.92 sp. gr. (22.05° B.), 435° flash test, 500° fire test, and about 550° B.P. The object of the high fire test is to ensure the oils being so free from volatile matter that none will be carried off with the moisture of the substance. The oil must be heated in advance, as it absorbs moisture from the air when exposed.

We have noted already the danger of explosion from the contact of sodium peroxide* and combustible agents as proved by Dr. A. Dupré. In the *Jour. Soc. Chem. Ind.* **16**, 492-494; 1897, in "A Note on a Possible Source of Danger of Fire during the Transport of Barium Peroxide," he shows that a mixture of wood-meal and barium peroxide inflames when struck by a two-pound steel weight falling 40 inches upon a steel anvil or by a glancing blow with a wooden broomstick.

Mr. G. E. Barton presents in the *Jour. Am. Chem. Soc.* **19**, 500-509; 1897, an admirable article, "On the Manufacture of Dynamite." In our review of Guttman's "Manufacture of Explosives," † we have referred to his failure to give the American practice in this manufacture. Mr. Barton's paper supplies this deficiency. It may also be read in connection with description of the Adeer factory referred to below.

William H. Krug and J. E. Blomen give, in the *Jour. Am. Chem. Soc.* **19**, 532-542; 1897, the results of their laboratory experiments on the "Commercial Preparation of Nitro-naphthalenes." The paper opens with some statements regarding the commercial uses of the nitro-naphthalenes which include many instances of proposed use that have never gone into practice. The authors give the results of many experiments made to nitrate naphthalene, and find that it is impossible under the conditions existing to prepare nitro-naphthalenes from α -naph-

* Proc. U. S. Nav. Inst. **21**, 827.

† Proc. U. S. Nav. Inst. **21**, 833, 1895.

thalene-sulphonic acid; that nitro-naphthalenes are best prepared by treating naphthalene with a mixture of sulphuric and nitric acids; that the highest yield is obtained when an excess of sulphuric acid is used; that the degree of nitration, as characterized by the melting point, increases with the amount of sulphuric acid present, though an excess has the opposite effect.

To obtain nitro-naphthalenes for commercial purposes it is best to use nitric acid of 36° B. The amount of sulphuric acid to be used varies with the nitration degree desired, and ranges from 4:1 (nitric:sulphuric) for low melting products, to 3:2 for the higher derivatives. Too large an excess must be avoided, as it chars the product and produces a tarry useless end product. In all cases the product of these processes is a mixture of different nitro-naphthalenes.

“The great Dynamite Factory at Adeer” is the title of a popular illustrated article published by H. J. W. Dam in *McClure's Magazine* 9, 823–836; Aug., 1897. The article is jauntily written and somewhat misleading, but from it we gather that the works contain 450 separate structures, covering 400 of the 600 acres owned by the Nobel's Explosive Co. at this place; that 200 girls and 1100 men are employed in the factory; that the nitrating charge is 1.5 tons of sulphuric and 1 ton of nitric acid to 700 pounds of glycerine, giving a yield of 1500 pounds of nitroglycerine in 55 minutes running time, the lead convertor with compressed air being used; that all persons entering the “danger area” are rigidly and repeatedly searched, and that all metallic objects—watch, money, penknife, scarfpin, match-case, matches, and keys—are taken from one, while the women are forbidden wearing pins, hairpins, shoe buttons or metal pegs in their shoes or carrying knitting, crochet or other needles; that the employees in the danger area are conspicuously uniformed, nitrators in scarlet, carriers of explosives in dark blue, smokeless powder men in light blue, cartridge girls in dark blue; that the constant absorption of the nitroglycerine stimulates the amorous tendencies of the employees; that magazine shoes of rubber or leather must be worn in every danger house; that the dynamite made here contains about one pound of carbonate of ammonia to twenty-five of kieselguhr and seventy-five of nitro-glycerine; that special magazines are pro-

vided for testing the behavior of the various explosives during exposure for long periods to high and low temperatures; and that thirty thousand tons of dynamite have thus far been transported on English and Continental railways without an accident. The site of the factory, on a barren waste of sand-dunes, stretching for one and three-quarter miles along the sea, was selected by Mr. Nobel in 1871.

Arms and Explosives 5, 151; 1897, in its report of the annual general meeting of the Nobel-Dynamite Trust Co., Ltd., says that the chairman stated that their trade with Mexico was threatened by the United States factories, and "in order to protect this trade they were considering the advisability of establishing factories both in the east and the west of the United States." The New York *Herald* recently records the purchase of upwards of 600 acres of land in Middlesex county, N. J., for this purpose, where a factory is to be erected which it is expected will give employment to upwards of 1000 men.

Through the courtesy of Lieut. W. R. Quinan we are in receipt of the following interesting "Account of an Explosion" which occurred September 1, 1896, at the California Powder Works, Pinole, California:

"On September 1, about 1.05 p. m., there was a disastrous explosion at these works, resulting in the killing of four white men and eight Chinamen, the destruction of the new nitroglycerine house, the nitroglycerine storehouse, the mixing house, and the usual damage to many other buildings. The nitroglycerine house and storehouse were part of the new works recently built at great expense to the company. Of this plant, the ammonia refrigerating plant and acid cooling house escaped without serious injury. These new works had only been running three days.

"The trouble originated in the nitroglycerine house. Some buckets of nitroglycerine were drawn by the workmen from a waste tank in the basement of this house and brought up to the wash-tank floor and placed on a platform built around the wash-tanks. It was left there a few minutes preparatory to dumping it into the wash-tanks. Water was being drawn into

these tanks for the purpose. While the men were waiting for the tanks to fill—not more than a minute, some of them say—the nitroglycerine in the buckets decomposed spontaneously, but without immediate explosion. There was no other nitroglycerine stored in the house at the time. Two charges were still in the mixers, about ready for discharge. There were four men in the house. The foreman, William Ray, was in charge of the mixers, the other three were below on the wash-tank floor, where they had just been engaged in bringing up the buckets. All the men ran when they saw the evolution of fumes from the buckets. Exactly what took place can only be guessed at in detail, but this seems about the course of events: The decomposition in the buckets was accompanied with a puff, which probably scattered the fuming oil into the scale or weighing tank, thence into the filter tank below, thence it followed a rubber-lined V-gutter to the storehouse 250 feet distant. The switch was still in place in this house, and the decomposition was communicated to the remnant of a charge, probably about 600 pounds, still in one of the store tanks. A stream was running at the time from this tank in a V-gutter or flume to the mixing house, about 1400 feet distant. The decomposition having reached a body of the liquid, an explosion took place, which was transmitted almost instantly to the mixing house, destroying the flume on the way.

“All the men killed were at the mixing house. Three out of the four white men were caught by an unlucky chance. Two were on the ‘supply car,’ engaged in delivering nitre at the rear. Our track scales being out of order, they were weighing it on a portable scales brought from the warehouse, which made them a quarter of an hour later than usual on that trip. Crater, the foreman of the packing house, had just come to give an order for powder in time to meet his death.

“A few minutes, not more than two at most, after this explosion, the mixers in the nitroglycerine house exploded, destroying everything connected with that building except some sheds covering the outside waste tanks at the foot of the hill. This explosion probably came about in this way: The steam-pipe supplying the engine was broken by the explosion at the storehouse and the machinery was stopped. Fresh glycerine may have run into the mixers from above, or fire may have reached them from the decomposing oil below.

“This explosion differs from most in this: the men who saw the trouble begin lived to tell the tale. This was due to a feature in the new works. As fast as the nitroglycerine was made, purified and filtered, it was run away to the storehouse. If there had been any quantity in the house all the men would probably have been killed and we should have had another mystery with a dozen plausible theories, all of which would have been wrong.

“We have learned a valuable, if disheartening, lesson. It is that the nitroglycerine collected from the waste tanks is much more dangerous than ordinarily believed. The plan of handling it in buckets is the usual one in factories. We were not blind to its dangers, and took precautions not in general use, to purify it to a certain extent before it was drawn from the waste tanks. Its sensitiveness is no doubt due to an excess of impurities derived from the wash-water.

“When the trouble started, the conduit leading from the nitroglycerine to the storehouse was fairly drained. It was about time for the switch in the latter building to be turned. This was a long pivoted trough delivering into a tank of water when out of place. The man on this duty was detained a few moments too long in handling the buckets. If the switch had been broken, there is good reason to think that no serious harm would have resulted from the decomposition in the buckets.

“It is well to note as having a possible bearing on the cause of the trouble, that the quantity of nitroglycerine in the waste tank was unusually large. There were ten buckets of the stuff drawn off and carried up to the wash-tank floor. Nothing unusual was noticed in doing this. One of the men remarked that it was uncommonly clear and free from slums. The quantity was large for this reason: In addition to the usual quantity carried over mechanically from the wash-tanks and a little run down from the second separation, the nitroglycerine collected from the refrigeration of the waste acids at the cooling house was also run down into this tank as well as the wash-waters. This nitroglycerine was regarded with some suspicion, but it was given three careful washings in a lead wash-tank before it was allowed to run down.

“In regard to our waste and catchment tanks, we had a very elaborate system. Besides the one in the basement, from which

the sensitive oil was drawn, we had one at the acid cooling house and two at the foot of the hill below the nitroglycerine house. These escaped, though they had quite a quantity of oil in them. They were all built on the same pattern. Each tank was lead-lined, twelve feet long inside, and drained to one corner. Each tank was divided into four compartments by heavy lead curtains hanging down within a few inches of the bottom. In each compartment there was an air jet to keep the bottom liquid agitated. At the lowest point of the tank a jet of fresh water was introduced to produce a circulation and wash out any acid that might be present. Each tank had an overflow at the end. In regard to the chance of an accumulation of acid in the waste tank, this was rendered impossible. Water was flowing through the tank constantly, and the strong soda from the wash-tanks had to pass through the catchments going down under the partitions in close contact with the bottom liquid which was being stirred by the air-jets. The arrangement was intended to give the waste nitroglycerine a preliminary washing before it was drawn off. That it should have been so prone to decomposition in spite of all the care taken is very strange.

“The simplest view to take of the matter is this: Nitroglycerine, as the immediate product of the nitration of glycerine by mixed acids, is a complex substance. It probably varies considerably in composition from the presence of varying quantities of the lower nitrates and other impurities (some of which are unstable), depending upon the quality of the acids and the glycerine. With these natural and unnatural impurities adhering to it its behavior is very uncertain. Fortunately the impurities are soluble in fresh or alkaline water, and can be removed, leaving a liquid which is fairly stable and well defined in properties.

“The waste nitroglycerine collected in the catchments consists of that carried away mechanically in washing, and also of that precipitated by neutralizing the acid water, as both acid and alkaline waters dissolve more than fresh water or neutral solutions, and this waste nitroglycerine is especially dangerous, because it contains an excess of impurities from contact and mixture with the wash-waters.

“We were using an American glycerine—a brand which up to the time we had regarded as a standard in purity and good

behavior. For obvious reasons I do not mention the name of the manufacturer.

“ This explosion had several curious features. An explosion of nitroglycerine proper is free from fire; that, for instance, in the storehouse, a building which had double walls and floors packed with sawdust, though it made match-wood of the building, did not leave a scorched chip behind it. That in the mixers was very different. These were steel vessels with mechanical stirrers. In the short time intervening between the stopping of the stirrers and the explosion the oil had only partially separated from the acids. The explosion was violent enough to destroy the building, but a large portion of the nitroglycerine was an emulsion in the acids and escaped explosion, being scattered with the acids over an immense space. The breeze carried the magnificent yellow cloud toward the north. Grass fires were started in the stubble at a hundred different points within a radius of half a mile. For the first hour or two after the explosion the energies of our men were absorbed in fighting these fires. This was not dangerous work, except in the vicinity of the sheds covering the waste tanks still left standing at the bottom of the hill, near the site of the nitroglycerine house. It was rightly suspected that these tanks contained nitroglycerine (we recovered about 250 pounds from them next day). The fire was burning fiercely near them, and had already attacked the shed covering the last catchment—a small tank about twelve feet beyond the large waste tanks. The flume connecting this with the waste tanks was also on fire. Every few minutes there would be a report like a pistol shot, showing that the fire was coming in contact with small quantities of the liquid. In spite of the danger, some of our men were hastening to the rescue of the waste tanks, when the small tank exploded and did the work for them. The water in the tank was scattered around, and this, with the blast, completely extinguished the stubble, the flume was blown away, and although the large shed was badly wrecked, the waste tanks with their dangerous contents were saved. This is one of the rare instances in which a small explosion prevented a larger and a more serious one.”

A profusely illustrated article by Framley Steelcroft in the *Strand Mag.* **73**, 498-506; May, 1897, entitled “ Explosives,”

gives brief popular accounts of some among the more extensive explosions which have occurred. Perhaps the most interesting among the pictures given are the photographs of the Johannesburg explosion of February 10, 1896, and that of the great plume of smoke from the Antwerp explosion of September 6, 1889.

General Hawley introduced in the U. S. Senate, May 3, 1897, as S. 1874, 55th Congress, 1st session, a bill entitled "To regulate the importation of gunpowder, nitroglycerine and other explosive substances," which is the same as that given in No. XXVI of these notes.* No further action seems to have been taken than to refer it to the Committee on Commerce.

Mr. Richard J. Friswell, in a paper "On the Properties of Nitro-benzene," *Jour. Chem. Soc.* **71**, 1010-1013; 1897, says that during the severe cold of January, 1886, he obtained crystals from a drum of nitro-benzene which were $2\frac{1}{2}$ inches long, 1 inch broad, $\frac{3}{8}$ inch thick, and weighed 15 grams. From such pure material he determined the constants of mononitro-benzene, getting the following: Specific gravity of solid, $d_4^{15} = 1.344$, liquid, $d_4^{3.8} = 1.222$; $\frac{13}{4} = 1.2116$; $\frac{28}{4} = 1.1931$. Expansion on fusion, 0.099804. Contraction on solidification, 0.099837. Boiling point at 760 mm., 209° corrected.

Nitro-benzene is remarkable as giving a strongly colored vapor which resembles diluted chloric acid, and is visible in a 2 inch layer, and very marked in a 6 to 8 inch layer.

An editorial of the *Eng. and Mining Jour.* **64**, 242; 1897, on "Magazines for Explosives in Coal Mines," states that "the mining laws of most countries forbid the storage of explosives in magazines directly connected with the underground workings of collieries, though a few countries permit a small supply to be kept in such places. Thus the Austrian regulations permit 100 kilograms, but the magazines must be at least 100 meters from any gallery or shaft through which persons are passing. In Saxony depots to contain 75 kilograms are allowed not less than 50 meters from shafts and 10 meters from galleries, while larger amounts may be stored according to regulations prescribed

* Proc. U. S. Nav. Inst. **21**, 807-815; 1895.

specifically by the mining authorities. According to the French and Belgian laws, only enough explosives for a single day's work may be taken into the mine. Great Britain and many of her colonies have similar laws, and the anthracite and bituminous laws of the State of Pennsylvania are not in this respect essentially different from the more stringent of the European.

“Some of the French colliery managers, however, have desired to go further than the most liberal allowances in other countries, and several years ago made application to the Minister de Travaux for permission to store underground as much as 2000 kilograms of explosives. This application was referred to the Commission du Grisou, and under its direction numerous experiments have been carried out during the past four years to determine to what extent this practice might be safely allowed. M. Ledoux, Ingenieur en chef des Mines, has recently made a report on the subject to the Commission du Grisou, which is published in Vol. XI. of the *Annales des Mines*, 1897.

“The existence underground of large masses of high explosives which are likely to be ignited involves a great number of problems. In the opinion of the French Commission which studied them, the dangers resulting from the invasion into the mine workings of the vast volume of gases of an explosion were most grave. It was conceived, however, that these dangers might be obviated by the interposition of a buffer to work automatically between the magazine and the main gallery of the mine. A system was devised, therefore, whereby in case of explosion a stopper fitting tightly like a piston in the connecting drift would be thrown by an explosion against an annular shoulder, thereby sealing the drift and confining the expanded gases. A series of experiments performed on a small scale proved that this device would work satisfactorily, but the Commission would not endorse it unreservedly until a test on an actual working scale should be made. The interest of the Comité Central des Houillères de France and the Cie. de Blanzky in the matter enabled the Commission to make the desired experiments at Blanzky in December, 1895. A charge of 500 kilograms of 75 per cent. dynamite, enclosed in a gallery of 10 meters length and 5 meters square in section, so that the density of the charging was as 1:100, was exploded. The buffer, cylindrical in shape, was 1.5 meters in diameter and 1.5 meters long. It was built up of two-thirds cardboard and one-third of wood. It was thrown back against

an annular seat .25 meter wide. The chamber was 20 meters below the surface and was approached by an adit 50 meters long. The experiment was successful in every respect. No effect was observable beyond a dull rumbling sound, and no gas apparently was projected into the gallery of access.

“The Commission du Grisou has now laid down the following rules under which large quantities of explosives may be stored underground. Black powder is not permitted; caps cannot be kept in the same magazine with the explosives; boxes of explosives must be opened in a special chamber at least 20 meters from the magazine, and never in the latter. The illumination of the magazine must be exclusively by safety or electric lamps; boxes of explosives must be placed on shelves or benches, and never superposed; the quantity of explosive must be governed by the size of the magazine, so that the density of charge shall not exceed 1:100; good ventilation of the magazine is indispensable.

“The arrangement of the entries of the magazine, position of the magazine with respect to the surface and the working galleries of the mine, and the proper construction of the automatic buffer are described at considerable length; for these details reference should be made to the original paper.

“As to the charge-density, which, according to the commission, should not exceed 1:100, it is necessary to explain that this is worked out from the subjoined formula 1, while 2 gives the pressure produced by the explosion of a given weight of explosive:

$$1. \quad D = \frac{\pi}{V}; \qquad 2. \quad P = \frac{f}{\frac{V}{\pi} - a}.$$

“In these formulae π is the weight of the explosive in kilograms and V the volume of the chamber in liters, while f and a are coefficients depending upon the explosive. Thus in a chamber 5 meters square in section, containing 25 kilograms of dynamite in a box of 0.33 meter long, the volume V is $5.0 \times 0.33 = 1.65$ cubic meters = 1650 liters; and the charge-density, according to the formula, is $25 \div 1650 = 0.01515$. If $f = 9.360$ and $a = 0.709$, the pressure of an explosion in this case will not exceed 142 kilograms per square centimeter, while if the charge-density were 1:2 the pressure would be 7250 kilograms. With this disposition the pressure is independent of the quantity of explo-

sive in the magazine. The length of the magazine would be equal to $C \div 75$, in which C is the weight of the explosive, or for 2000 kilograms about 27 meters would be required.

“The position of the powder magazine is an important question, but the arrangements prescribed by the French commission for safety when it is located underground are so elaborate and expensive that it is doubtful if any besides managers of very large collieries will care to adopt them, notwithstanding the obvious advantages that are to be gained from storing explosives in this manner.

“In this connection, however, it is not out of place to refer to the carelessness with which dynamite is often stored underground in metal mines in States of this country where there are no regulations on the subject. There are numerous instances where the magazine is a small chamber opened from a main working gallery, and separated from it by nothing but a light door, not always tight, while within it the explosive is stored and handled with a carelessness that is appalling. That there are not more serious accidents from this source is doubtless because the practice is not very general, and prevails usually only in small mines where seldom more than a small amount of powder is on hand at any one time. There is no excuse, however, for such an accident as that at the Belgian mine at Leadville, Col., in September, 1895, where six men were killed and four more were injured. The supply of powder at this mine, kept in an underground magazine, exploded, the precise cause of the explosion being unknown, and caused a fall of rock which imprisoned the gases of the powder, thereby suffocating six of the gang of men who were at work 100 feet from the magazine.”

The exports of explosives from Germany according to U. S. Consular Reports **53**, 253; March, 1897, were as follows:

ARTICLES.	1893.		1894.		1895.	
	Quantity. Double Cent.	Value.	Quantity. Double Cent.	Value.	Quantity. Double Cent.	Value.
Explosives,	22,675	\$809,000	40,282	\$1,746,000	50,450	\$1,809,000
Fuses, powder, etc.	82,123	3,700,000	85,503	3,451,000	92,309	4,165,000

In spite of the closest competition, this year's business will be better than last year's. Sporting powder has hardly held its own, owing to the fact that there is a decrease in the world's demand for this article, yet German sporting cartridges, especially those which are loaded with smokeless powder, are in large demand.

The explosives go in largest quantity to South Africa (to the Cape and Transvaal), and then come, in the order named, Russia, England, Mexico, Chile, Australia, Japan, China, Denmark, and Sweden. The former falling off in sales due to the law forbidding the use of explosives in coal mines is now being made up by the sale of patented (nitro-substitution) explosives, in which the danger from use has been reduced to a minimum.

In the U. S. Consular Reports **52**, 574-576; December, 1896, the price of 75 per cent. dynamite in Cornwall is given as \$291.90, and in the west of Scotland \$324.97 per ton of 2000 pounds. The price per kilogram (220 pounds) in Hamburg was \$68.56 in 1893; \$75.32 in 1894, and \$61.10 in 1895.

As one of a series of articles on the Witwatersrand gold-field and its workings, Mr. W. Y. Campbell gives in the *Eng. and Mining Jour.* **64**, 190; 1897, an account of the "Mining Explosives in the Transvaal."

"The consumption of explosives in the Transvaal is broadly 200,000 cases per annum. A case is supposed to contain 50 pounds net. The consumption grows daily with the growth of the industry. In the infancy of the gold industry, less than ten years back, a monopoly was granted by the Pretoria government to a shrewd man from Hamburg. The object of the government was incidentally to sell local explosives to the mines, but principally to manufacture locally gunpowder and cartridges for its use and to be independent of imports through British ports. The object of the concessionaire was to make money. The result has been that he has become a millionaire by virtue of his shrewdly worded and shrewdly worked concession, but neither the government nor the industry has ever had a single pound of powder or of dynamite produced locally. At one time the concession was canceled, but a new concession, differently worded, was obtained, and this industry, which has some eleven years to run, embodies a monopoly in the manufacture of explosives and a monopoly of handling and selling.

"At the present time the prices of explosives are as follows:

PRICES, 1896-97.			
Trade name.	Nitro glyc. %.	Price per case.	Sales %.
No. 2 dynamite	65	80 s. (\$19.20) }	.15
No. 1 dynamite	75	85 s. (\$20.40) }	
Gelignite.....	80	85 s. (\$20.40) }	
No. 1 A gelatine dynamite..	85	98/6 (\$23.64) }	.85
Blasting gelatine	100	107/6 (\$25.80) }	

“These prices are net at depot; freight, and therefore total cost, varies with the distance of consumers from depot. Blasting gelatine forms 60 per cent. of the total consumption.

“The Transvaal is the finest market in the world for mining explosives, therefore, and all the world's manufacturers have been eager to compete, but in vain, as the Nobel group is in possession under the government grant and fixes prices its own way. The mine owners have repeatedly proved that with free trade their explosives would not cost much more than \$11.40 a case, against the present average cost of \$24.

“The costs per ton mined vary from 25 to 75 cents, while in other parts of the world isolated mines show 10 to 25 cents; 10 cents is the Alaska-Treadwell figure, and that is an isolated mine in remote Alaska. The special levy made by this monopoly on the industry here probably reached a total of \$6,250,000 up to the end of 1896. The charge for 1897 will be \$2,500,000 more than it would be with free competition, subject only to police and safety regulations.

“The consumption of dynamite, of course, varies per foot driven or sunk, or per ton raised, in the various mines with the various rocks dealt with. The cost of explosives per ton mined varies from 32 to 84 cents in the gold mines, and from 10 to 30 cents in the coal mines; gunpowder for the coal mines and other explosives for gold and coal mines are also barred entry into the State; and scientific advances and improvements in mining explosives are not allowed to benefit these mining ventures, unless the monopolists introduce them.

“The above is the mine owners' view and experience, but the monopolists claim that there is no such thing as 'free trade in mining explosives' outside the United States.

“They say that the Alaska-Treadwell figures are useless, for they are for a low-grade explosive that would not work in the Rand quartzites. They have spent \$4,500,000 cash in building a new factory in the Transvaal, and for that risk and expenditure they claim a right to a monopoly. The mine owners retort that they want to buy all mining materials in the best and freest markets, and they are prepared for cancellation of the contract under fair compensation and taking it over as a mines factory on a co-operative system, selling out at cost price. The fight is ten years old and no end in sight. Doubtless, owing to the very intensity of the

economic evil, a remedy will ensue soon; probably the government will buy out the concessionaires and content itself with police supervision of explosives. Then the mines can have a co-operative factory or buy in the cheapest and best markets.

“The following figures of dynamite costs for the year 1896 in one of the best-managed deep-level mines are of interest. During 1896, 833,392 cubic feet of rock were blasted; 64,100 tons of rock were removed, and 10,885 lineal feet of driving and sinking completed. Dynamite cost per cubic foot blasted, 8.8 cents; per ton of rock removed, \$1.15; per foot lineal, \$6.85. The work done was the development usual in getting at ore and exposing it by levels.”

The *Eng. and Mining Jour.* **64**, 244; 1897, says, regarding the “Dynamite Manufacture in British Columbia”: “There are three establishments in this province where explosives are manufactured for mining purposes. The Hamilton Powder Company, of Montreal, has works at Northfield, near Nanaimo, and the Giant Powder Company, of San Francisco, Cal., has works at Cadboro Bay, a few miles from Victoria. A third and small plant is making dynamite near Balfour, near the entrance to the west arm of Kootenay Lake. At Victoria sulphuric, nitric and hydrochloric acids are being made by the Victoria Chemical Works, which supply the powder manufacturers.”

The important service which the late Alfred Nobel rendered in the development of modern explosives makes it appropriate that a brief mention, at least, of his life and work should be recorded in these Notes. We are indebted to the courtesy of the well-known Ingénieur-Conseil P. F. Chalon for a copy of *Le Temps* of February 18, 1897, which contains a romantic account of Nobel's life, with an attempted analysis of his character, together with much private information. We find also a somewhat extended biography of Nobel, with a portrait of him, in *Arms and Explosives* **5**, 54-55; 1897, while the current press has given much regarding him.

From these sources we gather that Alfred Nobel was born of Swedish parents in Stockholm, October 21, 1833, being the third of four sons. Shortly after Alfred's birth his father moved to St. Petersburg, where he manufactured gunpowder for the

Russian government, invented a torpedo and erected the engineering works which have since become well-known for the small arms and agricultural implements produced in them.

Alfred Nobel was educated as an engineer and chemist, his studies being carried on in Russia, Sweden and England. His linguistic attainments were extensive. He was an omnivorous reader, and took a lively interest in the progress of science, being especially devoted to chemistry and to social science.

He began the commercial manufacture of nitroglycerine in Sweden in 1862. Notwithstanding the extreme hazard attending this enterprise; that his younger brother was killed by an explosion at these works not long after their establishment; that the manager of his newer works at Krümmel, near Hamburg, was killed in 1864; that numerous other disasters occurred; and that, as a result of these accidents, the transportation and use of the explosive were interdicted by law, Nobel persisted in his investigations by which to perfect the processes of manufacture and purification and the methods of transportation and use, and eventually achieved such success that factories for the manufacture of nitroglycerine are now established in all parts of the world and the output has risen from 11 tons per annum in 1867 to over 15,000 tons per annum to-day.

His first patent for "a mixture of ordinary gunpowder with nitroglycerine" was taken out in 1863. He invented "Dynamite," in which the nitroglycerine was absorbed in and retained by a porous solid, like infusorial silica, in 1866. In 1875 he invented "Blasting Gelatine," in which the nitroglycerine is incorporated with soluble gun-cotton to form a plastic, jelly-like mass, and in 1887 he invented "Ballistite," which is formed from the same materials as the preceding one, but in which the soluble gun-cotton is in such large proportions that the product is a solid celluloid-like body which burns, but does not detonate, and which is therefore used as a propellant. With these as bases he formed many mixtures adapted to special purposes.

These, with the discovery of the method of firing by detonation, are the more notable among the many achievements of this daring and resourceful man. There seems to be little record of his writings, but we note "*Les explosifs modernes*,"* which was delivered as a lecture before the Society of Arts, London,

* Paris, Lahure; 1876.

May 21, 1875, and "A bas les armes," which has been translated into several languages.

It is a pleasure to relate that he secured a well-merited reward for his enterprise and application, and that from his inventions in explosives and his association with the firm of Nobel Brothers & Company in the development of the petroleum fields of Russia he accumulated an enormous fortune.

He died December 10, 1896, at his villa at San Remo, and when his will was opened he astonished the world by his munificence and the novel uses to which his bequests were to be put. This is best described in the following extracts from the report of Minister Ferguson, published in U. S. Consular Reports 54, [201], 330-331; 1897:

"I inclose an extract from the will of Alfred Nobel, dated Paris, November 27, 1895, and which, after disposing of about 2,000,000 kronor in legacies to relatives, servants, etc., directs that the remainder be devoted to the objects set forth in the extract given below. The amount thus devoted to the advancement of science and literature is estimated to be between 30,000,000 and 35,000,000 kronor, and it is thought that it will yield 3 per cent. per annum income, or from \$240,000 to \$270,000, to be annually distributed in five prizes. Each individual prize will therefore be worth between \$48,000 and \$55,000.

"Messrs. Ragnar Sohlman, of Bofors, Sweden, and Rudolf Liljequist, of Stockholm, Sweden, who now resides at Bengtsfors, Uddevalla, are named executors. I have written to them for information.

"I understand that several of the heirs at law of Mr. Nobel are contesting the will, and that it may possibly be years before the executors will be able to distribute the prizes."

The extract is as follows:

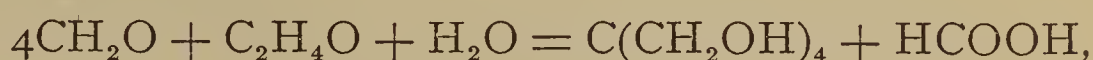
"My total remaining fortune, when capitalized, shall be disposed of in the following way: When the capital has been converted into good securities by the trustees, it shall form a fund, the interest of which shall be distributed annually as prizes to those persons who shall have rendered humanity the best services during the past year. The interest shall be divided into five equal portions, which shall be distributed as follows: One-fifth to the person having made the most important discovery or invention in the science of physics, one-fifth to the person who has made the most eminent discovery or improvement in chemistry, one-fifth to the one having made the most important discovery with regard to

physiology or medicine, one-fifth to the person who has produced the most distinguished idealistic work of literature, and one-fifth to the person who has worked the most or best for advancing the fraternization of all nations and for abolishing or diminishing the standing armies as well as for the forming or propagation of committees of peace. The prizes for physics and chemistry shall be awarded by the Royal Swedish Academy of Science; that given to works of physiology and medicine by the Carolinska Institute at Stockholm; the prize for literature by the Royal Swedish Academy at Stockholm; and the prize given to the propagators of peace by a committee composed of five members who shall be selected by the Norwegian Storting. It is my absolute wish that no importance shall be attached to any difference of nationality in awarding the prizes, which, consequently, shall be given to the most competent person, whether Scandinavian or not."

A rather vigorous criticism of the provisions of this will is to be found in *The Spectator*, p. 47, January 9, 1897.

Bruno Thieme, of Sieburg, Germany, has been granted U. S. Patent No. 541,899, of July 2, 1895, for a "Process of making Nitropentaerythrit" for use as an explosive. The claims cover a method of producing a compound for use as an ingredient in explosives, termed nitropentaerythrit, by treatment of pentaerythrit (produced by the condensation of acetaldehyde and formaldehyde in the presence of lime) with concentrated nitric and sulphuric acids.

The reaction given for the formation of the pentaerythrit by the above process is



and for the formation of the nitropentaerythrit he gives



The synthetic method for preparing pentaerythrit is given in *Annalen* **265**, 316.

Pentaerythrit naturally suggests the body known as erythrite (also erythrol, erythro-glucin, phycite and butane tetrol), which is regarded as a tetracid alcohol, having the formula $\text{C}_4\text{H}_6(\text{OH})_4$. Erythrol occurs free in the *Protococcus vulgaris*, and is found combined with orsellinic acid, as erythrin, in many of the lichens and algae. Erythrol may be obtained from erythrin by saponification with sodium hydroxide or milk of lime. It is readily soluble in water, difficultly soluble in alcohol, and insoluble in

ether. Erythrol possesses a sweet taste, and crystallizes from water in large quadratic crystals.

When dissolved in fuming nitric acid nitroerythrit, or better, erythryl nitrate, crystallizes in brilliant plates which burn with a bright flame and explode like nitroglycerine when struck.

On the further study of "Nitrogen Chloride," W. Hentschel (*Ber. Berl. Chem. Ges.* **30**, 1434-1437; 1897) finds that it is soluble in benzene, chloroform, carbon disulphide and ether; that the substance may be preserved in the solutions for some time in the dark, but that it decomposes rapidly on exposure to a bright light, and that the solvents present so diminish the sensitiveness of the nitrogen chloride that, for instance, a 10 per cent. benzene solution can be ignited or poured upon a red-hot plate without a serious explosion resulting. The solutions are sulphur-yellow, strongly refracting liquids. The solution in benzene is easily obtained by adding ammonium chloride to a 5 per cent. solution of sodium hydroxide which has been treated with chlorine, and agitating the mixture with benzene. About seven-eighths of the active chlorine of the aqueous solution is converted into nitrogen chloride and there is obtained a clear, strongly refractive sulphur-yellow liquid possessing the repulsive odor characteristic of nitrogen chlorides.

The benzene solution, on decomposition by sunlight, gives nitrogen and benzene hexachloride; the carbon disulphide solution gives sulphur chloride; the carbon tetra-chloride gives nitrogen and chlorine; while the chloroform and ether solutions yield ammonia in place of nitrogen, ammonium chloride separating out and hydrogen chloride and chlorine being evolved. The chloroform also yields a trace of hexachlormethane, and the ether a liquid which boils at 80° to 150° and which contains chlorine and reduces silver chloride.

In a paper on "The Naval Weakness of Great Britain," by Sir Charles W. Dilke, *Cassier's Mag.* **12**, 425-440; 1897, after speaking of the necessity of a more complete preparation for war, he says: "In addition to the deficiency in those battleships, the numbers of which are vital to us, there are, as I have said, some points of doubt which are disagreeable to contemplate. The French carry high explosive shells in all their ships, and they

count upon the rapid destruction of the unarmored and of the lightly armored portions of our battleships by means of these shells in an engagement, and believe that the poisonous fumes which the shells emit would render large portions of our armament unusable.

“Our own sailors think high explosive shells unsafe, and the fifty H. E. shells per ship that are now carried by our Channel squadron (and there are none, I believe, carried by any of our other ships) seem to have been taken on board to satisfy public opinion. I am told that the fuses are at the wrong end, so that they are useless for armor piercing, because we have found that we cannot safely use them with the fuses at the right end. The French say that they can so make use of theirs.

“We do not appear to be in possession of shells of the same construction as the French shells, which are carried in the tropics in refrigerating chambers. Our officers generally think our own H. E. shells both useless and dangerous, and probably in time of war would drop them overboard. This is not the case with the French, and, therefore, presumably the French have a safer and better pattern of melinite shell than that which we have been able to supply; and it must be remembered that the French communicate to the Russians the whole of their inventions, and even manufacture, when necessary, for the Russian government.

“French authorities state that melinite is safer than picric acid, and this, which is the basis of a common yellow pigment, is carried everywhere. In the report on the French naval budget for 1897 it is admitted that the French navy and the French army hold different views as to the power of piercing thin steel armor with H. E. shell.

“The navy contend that they can at least explode thin shells within the plate, thus making a big hole, and that all behind will soon lie open and be swept by a fire in the explosions of which no man can breathe.”

Through the courtesy of H. M. Inspectors of Explosives, we have been enabled to secure a copy of the second edition of “A Dictionary of Explosives,” * by the late Lieut-Col. J. P. Cundill, R. A., which is entirely rearranged and brought up to December,

* London, Eyre & Spottiswoode, 1895, 8vo.

1894, by Capt. J. H. Thomson, R. A. A comparison with the first edition shows that the topics are now arranged in alphabetical order, instead of the inconvenient subdivision into classes of the former edition; that the introductory matter has been increased from 15 up to 44 pages, and the dictionary proper from 108 up to 183 pages, it having at the end a valuable "Index to Ingredients" of explosives. Owing to the misuse which has been made of the former edition, this book can now only be purchased by permit of the Home Office.

The Smokeless Powder Company, Limited, has issued for circulation the lectures delivered by L. G. Duff Grant at the Museum of Practical Geology, October 28 and November 4, 1896, under the title "Smokeless Powder: its appliances, practice and purpose." * The lectures are issued in two parts, the first being devoted to a general survey of explosives and smokeless powders, the second to a description of the works of the company and the results obtained with their product. This second part is quite extensively illustrated. It would appear from the statements on pages 12-14 of Part I that the position of cordite is not yet assured.

"Nitro-Explosives," † by P. Gerald Sanford, is announced as a practical treatise on the properties, manufacture and analysis of nitrated substances, including the fulminates, smokeless powder and celluloid. The book shows that a considerable amount of material has been collected, but the not infrequent "slips" show that he is not practically familiar with the arts about which he writes, while errors in proper names, which are by no means infrequent, show that he has been careless in reading or transcribing. The errors are so frequent as to mislead any but those who are thoroughly conversant with the subjects treated of.

Through the courtesy of Professor Louis Amateis, we are in receipt of "Ascanio Sobrero. Notizie Biografiche," ‡ by Professor Vincenzo Fino. This appears as a reprint from Vol. 31 of the

* London, Smokeless Powder Co. Ltd. No date.

† London, Crosby, Lockwood & Son. 8vo, 270 pp. 43 ill.

‡ Torino, Camilla e Bertolero, 1889, pph. 35 pp. 8vo.

Annals of the Academy of Agriculture of Turin. There is appended a list of the published writings, numbering 123 titles, from which it appears that, in addition to his notable discovery of nitroglycerine and his researches on other explosive nitrates, he gave much attention to mineral analysis, collaborated in research with Avogadro and other eminent chemists, and published a manual on chemistry as applied to the arts, in four volumes. He was born October 12, 1812.

J. B. Baillièrre et Fils, Paris, announce "Les explosifs et les explosions" au point de vue medico-légal by P. Brouardel, Dean of the Faculty of Medicine of Paris, and "Dynamite et dynamiteurs," Les engines anarchistes, 1894, no author being given.

The eminent bibliographer, Dr. H. Carrington Bolton, has just called our attention to a "Bibliographical Index to the Russian and Foreign Literature of Explosives from 1529 to 1882,"* by A. Heckel. We are able to quote the title only, as the work itself is not accessible to us. It is a curious coincidence that this work should have appeared simultaneously with the annotator's "Index to the Literature of Explosives," and it is to be noted that neither of them is recorded in Guttman's Bibliography appended to his "Manufacture of Explosives," published in 1895.

Arms and Explosives 5, 74; 1897, contains an extended review of "A Bibliography of Guns and Shooting,"† by "Wirt Gerrare," in which the work is spoken of in the most approving terms. The main body of the work appears to have been brought up to July, 1894, and an appendix added to bring it up to the end of 1895. The author's name is William Oliver Greener. It is odd that the reviewer should have omitted to give the date of publication, which is presumably 1896 or 1897.

The Neues vom Büchermarkte of the *Mitt. gegen. Artill. u. Genie-Wesens*, page 439, 1896, simply notes "Das Dynamit und seine cultur-historische und technische Bedeutung,"‡ by Nobel.

* St. Petersburg, 1886.

† Roxburghe Press.

‡ Wien, 1896.

"A Hand-book of Modern Explosives," * by M. Eissler, is the second edition of a now well-known book first published in 1890. This new edition is enlarged by about one hundred pages and fifty illustrations. The principal additions treat of the testing of the materials for the manufacture of nitroglycerine, the recovery of the spent acids, and the properties of frozen nitroglycerine explosives, while an entire new chapter is devoted to nitrogelatine and gelatine dynamite in their practical applications. It is unfortunate that the book should be marred by errors, and especially that the formulas given for calculating the results of analysis in the tests of acids should be wrong.

* London, Crosby, Lockwood & Son, 1897. 8vo, 406 pp. 153 ill.

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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

NOTES ON THE LITERATURE OF EXPLOSIVES.*

By CHARLES E. MUNROE.

No. XXIX.

The "Twenty-first Annual Report of Her Majesty's Inspectors of Explosives" shows that the growth of the trade in explosives in Great Britain continues to increase notwithstanding the restrictions and governmental supervision imposed by the Explosives Act, five new factories having been licensed during the year and seven applications for licenses being still pending, while seven new magazines were licensed and nine others pending. The areas of the existing factories have also been enlarged so that, for instance, the site occupied by the Nobel's Explosive Co. Ltd., at Ardeer, is four times as large as it was when the Act was passed, while the number of buildings occupied by the company has increased in a similar proportion.

There was imported during the year—

Amorces	2,540 pounds.
Bellite	44,250 "
Blasting gelatine	27,500 "
Carbonite	579,000 "
Cooppal's powder	3,950 "
Dahmenite A.	26,450 "
Dynamite	179,000 "
Emerald powder	5,000 "
Fulminate of mercury	9,400 "

* As it is proposed to continue these notes from time to time, authors, publishers and manufacturers will do the writer a favor by sending him copies of their papers, publications and trade circulars. Address, *Columbian University, Washington, D. C.*

Gun-cotton	56 pounds.
Gunpowder	66,528 “
Gelatine dynamite	416,650 “
Fireworks	556,920 “
Matagnite gelatine	57,050 “
Normal smokeless powder	178 “
Normal sporting powder	6,215 “
Pigou's smokeless sporting powder....	1,000 “
Tonite	1,862 “

and 9,780,000 detonators.

The total number of factories now in operation in Great Britain is 139, making 53 different kinds of explosive materials, yet but one person was killed during the year from an accident occurring during manufacture. The total list of accidents is as follows:

SUMMARY OF ACCIDENTS.

	Accidents causing loss of life and bodily injury.			Accidents not causing loss of life or bodily injury.	Total number of Accidents.
	No. of Accidents.	No. of Killed.	Persons Injured.		
Manufacture	20	1	25	26	46
Keeping	6	6	4	3	9
Conveyance	1	—	2	1	2
Use and miscellaneous....	76	26	80	1	77
	—	—	—	—	—
Total.....	103	33	111	31	134

Under use and miscellaneous are included all accidents which occurred in the use of explosives and immediately connected therewith; also accidents in thawing nitroglycerine preparations, and others arising from miscellaneous causes not within the prohibitions of the Act. In short, this group comprises all accidents occurring under circumstances not immediately controlled by the act except the non-fatal, purely mining accidents with gunpowder under the Inspectors of Mines. It is natural to expect that the larger number of accidents will occur in use, as the explosives here get into the hands of many careless and untrained persons who are frequently free from supervision; yet numerous as the casualties for the year are, the number of killed was considerably below, and of wounded slightly below, the average for the preceding ten years.

As we have before remarked, these statistics would have greater value if accompanied by a statement of the amount of explosives produced and the amount of explosives consumed each year in the territory covered by the Act, and we are inclined to believe that if this were done the beneficent operation of the Act would be more strikingly shown.

An analysis is made of these casualty statistics on the basis of the number of factories in operation and persons employed, and it is pointed out that for the seven years immediately preceding the Act there was recorded an annual average of 39.5 deaths as based on the imperfect, non-compulsory returns from 55 factories only, whereas the average for the past ten years (there being now 139 factories and over 10,000 persons employed) the average for deaths is 5.1 (or about one-twentieth per cent. of the total number employed), and for injured 18.6 (or about one-fifth per cent. per annum). The saving in life is the more notable when it is recalled that a large proportion of the new factories established since the Act went into operation deal with entirely new classes of explosives and therefore with new forms of risks.

During the year the following substances were added to the list of authorized explosives: *Normal sporting powder*, consisting of nitro-cotton thoroughly purified, mixed or incorporated with potassium or barium nitrates or both of them, and paraffin or vaseline, both free from mineral acid, the whole gelatinized by a suitable process, grained and polished with or without graphite. *German spills*, consisting of cylindrical cases of paper, one-half charged with fuse composition, consisting of potassium nitrate, sulphur and charcoal, the other half containing a charge of gunpowder, the whole composition and gunpowder not to exceed two pounds to the gross, primed at one end with touch paper, and at the other with mealed gunpowder, or primed at both ends with mealed gunpowder. *Pettinger's electric fuses*, consisting of a cylinder of wood or other suitable material, containing two insulated copper wires, the ends of which, whether or not connected by means of a fine wire of platinum or other suitable material, are embedded in a priming composition, consisting of an intimate mixture of potassium chlorate, native antimony sulphide, copper subsulphide or subphosphide, silver (precipitated), plumbago, charcoal and bismuth. *Pettinger's electric detonator fuses*, consisting of Pettinger's electric fuses as above described and having attached thereto a detonator. *Kynite*, consisting of

not more than 27 parts by weight of thoroughly purified nitroglycerine (with or without the addition of not more than half a part of sulphuretted benzol), and with or without such other ingredient as may from time to time be sanctioned by a Secretary of State, uniformly mixed with not less than 75 parts by weight of a pulverized preparation, consisting of wood meal, not less than 40 parts, nitrates of potassium, barium, and sodium (or either of them), not more than 36 parts, and carbonate of sodium or calcium (or either of them), not more than half a part; such preparation to be sufficiently absorbed when mixed in the above proportions to prevent exudation of the nitroglycerine. *Oven blowers*, consisting of a short cylinder of paper dubbed at one end and charged with gunpowder, and having inserted in the other end a piece of quick-match encased in paper, projecting about four and one-half inches from the cylinder, the end of which is choked and tied, the projecting end of the quick-match being dubbed and coated with sulphur and the cylinder being afterwards flattened in a cracker mill.

Dr. Dupré's report is as usual full of interesting matter. It will be recalled that after investigation the amount of composition which was permitted in amorces was limited to .07 grains per amorce, it having been determined that this was a quantity which would prevent explosion *en masse*. An explosion which occurred at Kingston-upon-Hull in September in which several gross of boxes were destroyed gave rise to considerable apprehension in this regard. Fortunately a number of boxes from the same consignment and of the same manufacture were recovered from the shop after the explosion and examination showed that although the *average* proportion of explosive matter contained in the amorces was within the limit laid down, a not inconsiderable number of the individual amorces exceeded, and some very largely exceeded, this limit. Previous experiments had clearly established the fact that the safety of these amorces depends not so much on the average proportion of explosive matter contained in 1000 amorces as upon the fact that no individual amorce should exceed this proportion, since the larger amorce plays the part of a detonator, capable, if it contains too great a proportion of explosive matter, of exploding the whole, and this accident but confirms this deduction from the results of experiments.

Among the results of tests Dr. Dupré reports that 10 out of 113 samples of gelatine dynamite No. 2 and matagnite gelatine were rejected, four from failure to stand the heat test and six on account of exudation. The failure to stand the heat test may perhaps be due to the injurious effects exercised by some kinds of wood meal, but it is difficult to understand why, considering the absorbing power of the wood meal present in the gelatine dynamite, exudation should be more prevalent among samples of gelatine dynamite than among blasting gelatine.

The tests of five samples of American smokeless powder are recorded. "Four of the powders, American E. C., Hazard, Dupont, and Kings, closely resemble well-known English powders, consisting in greater part of nitro-cellulose, mainly of the soluble variety, with the addition of some nitrate of barium and potassium. The two first stood our heat test perfectly, and were well manufactured, the rest passed the heat test indifferently well, while the fourth stood the test for $6\frac{1}{2}$ minutes only.

"The so-called 'gold dust' differed, however, widely from any of our English powders; it consisted of picrate of ammonium, picrate of potassium, picric acid, and bichromate of ammonium. It was exceedingly violent in its action and appeared to be a rather dangerous powder to use in a shotgun."

The new explosives examined during the year were *bonnite*, which, like Kolf's powder, consisted of a mixture of different nitro-compounds, most of which are difficult to purify effectively. The first sample submitted was satisfactory as to its physical character and temperature of explosion, but it stood the heat test but two minutes on account of insufficient purification. The second sample passed the preliminary tests successfully, but lacked sufficient chemical stability to successfully resist prolonged exposure to 90° - 95° F., and it too was rejected. *Ripp-lene*, consisting of a nitrate mixture containing kerosene shale, was favorably reported on, subject only to the condition that the shale should be free from pyrites. *Patent blasting powder No. 1*, consisting of ordinary gunpowder mixed with a salt to prevent the production of flame on explosion, was also favorably reported on, as it possessed the required chemical stability.

Among the "Accidents" are two occurring in the manufacture of ballistite. In the first some sheets caught fire as they were passing through the rolls; in the second a small quantity exploded

in the press. The latter accidents have been thought due to the heat developed by the too sudden compression of the air in the interstices of the paste, but in this case the plunger was being withdrawn, and the accident is attributed to friction between the plunger and inside of the cylinder, where some accumulation of the paste is unavoidable.

The report on the fire occurring at the works of the Cotton Powder Co., Limited, near Faversham, on March 1st, develops the interesting fact that some 5000 to 6000 pounds of gun-cotton in water, which was exposed to the full effect of the fire, was practically uninjured, although in some cases the vats and vessels containing it were burnt away, and an even more important fact was the burning away inexplosively of over 3000 pounds of gun-cotton, containing about 30 per cent. of water, made for the War Office, and stored in barrels of $27\frac{3}{4}$ pounds each.

The most fruitful source of accidents in use has been during ramming, either from the use of improper tools or the application of undue force. As usual a preponderance of these accidents occurred in frosty weather when, owing doubtless to the explosive being hard, it is not so easily introduced into a rough or irregular hole, while the tendency to jam probably leads to an undue application of force. It is important to point out that in such circumstances even a wooden rammer is no protection, for more than half the rammer accidents were caused with wooden tools.

The accident at Kirkee, India, was of another sort. Two officers of the 28th Pioneers had cut some gun-cotton slabs into strips and dried them all day in the sun. One of the officers then attempted to ram these strips into a bore hole with a copper rod, when the charge exploded. No undue force appears to have been used and there is little doubt that the accident was due to the abnormal sensitiveness of the gun-cotton at the elevated temperature existing. The exceptional sensitiveness of nitro-cotton when heated, and especially when in a fine state of division, has been illustrated by more than one accident, and the circumstances of these accidents are fully dealt with in Special Report No. XLIV, of December 9, 1882.

The gravest accident recorded is that of the explosion of 55 "tons" of blasting gelatine at Braamfontein, near Johannesburg, South Africa, on February 19, 1896, in consequence of a rail-

way collision. The explosion produced a crater about 300 feet long by 65 wide and 30 deep in soft ground. There was total destruction within a radius of about 330 yards, while from that distance to 660 yards all the buildings were shattered, and roofs were battered in up to about 1000 yards. The buildings were chiefly of corrugated iron and mud, and therefore not of a substantial character. Fragments of iron were picked up at over 3000 yards. Windows were broken generally up to about 2000 yards, and in one direction, where the ground sloped toward the site, many windows were broken up to 5000 yards and some beyond that distance. These effects agree closely with those produced by the explosion of an almost equal amount of gunpowder at Erith in 1864, and the comparison is especially valuable, as in the "Table of Distances" used by the Inspectors in fixing the sites of factories and magazines the distances for 50 "tons" were derived from the data of the Erith explosion.

In another accident in South Africa at the Langlaate mine, Transvaal, a young man was so overcome by the poisonous fumes from the dynamite blasts in one of the levels, which filled the shaft, that he fell from the cage in the shaft on which he was standing and was killed.

An accident which appeals particularly to naval officers occurred in the magazine of the *Amiral Duperre*, flagship of the French Mediterranean Squadron, May 14, 1896, due to the explosion of a 34-centimeter cartridge in the midst of a lot of loaded shells, which fortunately remained intact. The explosion was attributed to the overheating of a steam-pipe passing through the magazine.

An explosion of ammonium nitrate at Paddington, March 20, and of bleaching powder, have especial interest to the chemist. In the first case the manufacturer was making "laughing gas" and had placed 18 pounds of ammonium nitrate in an open enameled iron pot on the furnace to melt when shortly the contents exploded, broke the pan and the iron plate of the furnace and blew down the brickwork. Although this property of ammonium nitrate has long been known* and was considered when the application of the Bellite Co. was before them, this is the first instance of such an accidental explosion brought to the notice of the Inspectors.

* Proc. U. S. Nav. Inst. 19, 92; 1892.

The explosion of bleaching powder, which was of a mild character, was reported to have occurred while a grocer was removing some bleaching powder from a barrel by means of an ordinary metal scoop. The bleaching powder, on examination, proved to be rather weak in chlorine, and contained nothing that seemed to throw any light on the nature of the alleged explosion. This is the second time an alleged explosion due to this cause has been brought to the attention of Dr. Dupré. We notice that "Bloxam's Chemistry," 7 ed., 162, 1890, speaks of bleaching as evolving oxygen so as to shatter the bottles, and heating up so as to set fire to the casks in which it is stored.

As usual there is a record of the big blasts of the year, the first being that at Bonawe Granite Quarries, Argyllshire, where 8 tons of gunpowder were fired. Six tons were placed in a chamber 125 feet from the surface and 65 feet from the face of the rock, and two tons in a second chamber 45 feet from the surface and 40 feet from the face of the rock, the distance between the two chambers being about 120 feet. The gunpowder used was especially manufactured for the purpose and contained 75 per cent. of saltpeter and was milled for three hours. The blast was estimated to have displaced 100,000 tons of rock.

The second blast took place at Dinorwic Quarries, Llanberis, and $3\frac{1}{2}$ tons of Nobel's gelatine were exploded, but no data as to the effect could be obtained.

A "petroleum accident" of special naval interest is one which occurred on board the Cunarder S. S. Servia when a party of men were engaged in painting the inside of a water-ballast tank. The tank, which was 3 feet 6 inches deep, was divided into 16 compartments with 18 inch aperture between each. The furthest compartment was being painted at the time and it was necessary to crawl through 15 of the small apertures to reach it. The paint used was styled Patent Bitumastic Solution and one of the survivors testified that it took him four to five minutes to reach the compartments, ten minutes to do the painting, and four or five minutes to return, and that he could not stoop down any longer as it made him dazed and queer in his head. All the witnesses testified that the use of the solution in confined spaces made them drunk and delirious if they remained any length of time at work. This is a well known effect of the lighter petroleums, and it is not surprising that the solution

was found to consist of coal tar dissolved in crude coal tar oil, having a flashing point of 45° F. Abel, and containing so much volatile matter that one gallon spread over a large surface would render 48 cubic feet of air inflammable.

Notwithstanding this the workman went into this inner compartment, which was already partly covered with the freshly-laid solution and containing a partly filled bucket of it, with a lighted candle. Sometime having passed without hearing from him another workman went to his assistance and found the place on fire and the man burned and delirious. He was so delirious as to fight against coming out and it took an hour and a half with assistance to get him through the apertures and up the manhole, and he afterwards died in the hospital from the effects of the disaster.

This report contains a copy of the Explosives in Coal Mines Order of 1896, a list of "permitted explosives" for use in coal mines, and much tabular matter of importance.

We have through these Notes repeatedly called attention to the dangers which accompany the use of explosives in coal mines, the results of experiments made by various commissions in France, Prussia and England, and the invention of various explosive materials especially intended for use in fiery mines. The more recent steps taken looking toward an increase in security in the working of these mines were, first, the Order in Council of the English Home Office of December 16, 1896, which prohibited the use of any explosive, other than a "permitted explosive," after July 1, 1897, in all coal mines in which inflammable gas has been found within the previous six months, or in the roads of all coal mines which are not naturally wet throughout, and after January 1, 1898, the use of any explosive other than a "permitted explosive" is absolutely prohibited in every part of such mines. Further, the use even of "permitted explosives" is prohibited unless (a) every charge is placed in a properly drilled shot hole and has sufficient stemming, not in any case less than 9 inches; (b) the apparatus or method used for igniting the charge shall be incapable of igniting inflammable gas or coal dust; (c) every charge shall be fired by a competent person appointed in writing for this duty by the manager of the mine,

and not being a contractor for any work in the mine involving the use of explosives, nor a person paid by such contractor, nor a person whose wages depend on the amount of material to be gotten; (d) each explosive shall be used in the manner and subject to the conditions prescribed in the schedule of "permitted explosives." The use of explosives is prohibited in any main haulage road or main intake unless all workmen have been removed from the seam in which the shot is to be fired and all seams communicating with the shaft on the same level, except the men engaged in firing the shot, and such other persons, not exceeding 10 in number, as are necessarily engaged in attending to the ventilating furnaces, steam boilers, engines, machinery, winding apparatus, signals or horses, or in inspecting the mine.

The Schedule of Permitted Explosives accompanying this order consists of ammonite, Ardeer powder, bellite No. 1 and No. 3, carbonite, dahmenite A, electronite No. 2, kynite, roburite No. 3, and westfalite. The composition of each and the method in which they are to be put up is given with great precision and, what is of particular interest, the strength of the detonator to be used is specified for each explosive. In the case of each nitro-glycerine explosive it is especially prohibited to fire it when in the frozen condition.

To secure more certain results a "Committee to inquire into the History of Explosives for Use in Coal Mines" was appointed by the Secretary of State, and through the courtesy of one of its members, Captain J. H. Thomson, R. A., we are in receipt of the "Report" * of this committee.

In its preliminary report of February 4, 1897, the committee considered the possibility of conducting its experiments in a coal mine, but concluded it would be fairer to use chambers where the conditions and tests could be made as uniform as possible; also the desirability of a small apparatus, but concluded that in view of the peculiar character of gas explosions no results would be trustworthy unless made in a chamber of considerable capacity and so arranged as to admit of experiments with air, gas and coal dust.

The committee then presented drawings of a suitable station to be erected at Woolwich and recommended an appropriation

* Eyre & Spottiswoode, London, 1897, 12 pp., 2 plates.

of \$7500 for its erection and proof. The full report of October 6, 1897, contains a description with drawings of the apparatus, which consists of (1) a horizontal gallery of wrought-iron tubing used to test the liability of an explosive to ignite mixtures of coal-gas and air, and (2) a vertical tube to test the effect on coal dust suspended in air.

The gas gallery is fitted at its outer end with a device for holding a diaphragm of varnished paper or other suitable material, and at the opposite end it is closed by a disc of wrought iron having an opening in the center which is closed by the muzzle of a cannon when the latter is run up into position. The cannon is a very strong steel-lined wire-wound gun, having a bore of a diameter about that of the usual bore hole, and it is mounted on a small trolley running on rails. To prevent accidents from the bursting of the cannon a concrete wall has been provided on the side on which the observers stand. The gallery is fitted with seven safety valves to remove the strain when the gas explodes, and these serve also as sight holes by which to observe any flame which may issue. As mere observation of this kind is somewhat untrustworthy, a tuft of gun-cotton yarn is used as an additional test of ignition and is securely fastened in a position at the end of the tube, where only an explosion of the gas can ignite it. Alongside the gallery is a gasometer fitted with a gauge showing its contents, and a centrifugal blower, which are connected by pipes with both ends of the gallery so that a circulation of air and gas can be maintained through the gallery, gasometer and fan.

In preparing to fire a charge in this portion of the apparatus, the cannon is loaded and run up to the gas gallery, the gasometer filled with a measured quantity of gas at atmospheric pressure, and then, by opening the valves with which the connecting pipes are fitted and starting the fan, this gas is driven into the gallery and air removed at the same time from the opposite end. By keeping up this circulation for about one minute a uniform mixture of gas and air is obtained with very little leakage. The valves are then closed and the charge fired, the results being ascertained in the manner indicated above.

The coal dust apparatus consists of a vertical tube resting on a bed of concrete, in the center of which another cannon is placed vertically, being fixed in position by slats of wood. The tube

is fitted, near its base, with an opening in its side, closed by a strong door, through which the loading of the cannon is effected, and also, near the top, with an air and observation hole. Into this tube coal dust is blown by a fan similar to the one referred to above, the dust being fed into the pipe by means of a hopper.

In operating this apparatus air is driven along the pipe past the hopper, from which it carries with it the necessary supply of coal dust, and so soon as the operator considers that sufficient coal dust has been blown into the tube the charge is fired.

The testing station consists of two buildings, one of which contains the gas gallery and fittings. This building is completely open on one side, and the second building, placed on this side of the first, is fitted with an observation slit for the use of those attending the experiments, and is also fitted up as an office and storehouse.

The conditions prescribed for making the test are: (1) No explosive shall be submitted for testing until it has been admitted to the Home Office List of Authorized Explosives; (2) the test will be carried out for each explosive with the size of detonator recommended by the manufacturer or person submitting the explosive, and every shot will be fired by electricity; (3) all charges to be stemmed with nine inches of clay well rammed; (4) each shot to be fired in the case or wrapper in which it is proposed to be employed in actual use; (5) each shot to be fired into a highly explosive mixture of coal-gas and air, the gas being supplied from the Royal Arsenal gas works; (6) the charges of explosives to be fired will be determined as follows: (*a*) in the case of explosives intended to be fired by a detonator, and commonly called "high explosives," the charge will be taken as the equivalent of 2 oz. of dynamite No. 1, containing 75 per cent. of nitro-glycerine, as determined by the enlargement obtained on firing the same in a lead cylinder tamped with loose sand; (*b*) in the case of gunpowder or any explosive not intended to be fired by a detonator, the charge will be taken as the equivalent of 6 ozs. of R. F. G. gunpowder, as determined by the enlargement obtained on firing the same in a lead cylinder tamped with loose sand and heavily weighted above with a mass of metal. (7) Each explosive to be subject to the following test: A number of shots shall be tried not exceeding 40. If in the first 20 no failure occurs, or in the first 30 only one failure, or in 40 only two failures,

it will be passed. A shot will be regarded as a failure if (a) it ignites the gaseous mixture, or (b) it leaves an appreciable amount of the charge unexploded. A shot may be repeated at the discretion of the officer in charge of the testing, if in his opinion there is reasonable ground to believe that a failure was due to any cause unconnected with the explosive. The proposed fee for an original test is £25, for a second trial £15, and for retesting from time to time, not to exceed 10 shots, £2. Since June 5, when the apparatus was first tried in the presence of members of the Institution of Mining Engineers, upwards of 700 shots have been fired and in no case has any accident occurred to the apparatus, although the cannon have been subjected to pressures estimated at over 100 tons to the square inch. Owing, however, to the high temperatures and pressures at the time of firing the erosion of the hardened steel lining tubes has been so great that it has been necessary to insert a fresh liner after about 200 shots.

The report discusses in detail the use of coal-gas versus fire damp, uniformity of gaseous mixtures, method of electric firing, method of determining an explosion, nature and quality of stemming, usefulness of firing unstemmed shots, size of charge, method of determining comparative power of explosives, size of detonator, delayed ignitions and other important matters.

It may not be amiss to inquire how the system of determining rejections was arrived at, for it is not apparent in what respect an explosive which fails once in the third ten rounds or twice in the second twenty is better than one that fails once in the first ten rounds or twice in the first twenty, or even better than one which fails twice in the first ten rounds. Of course the assumption probably is that a failure in the first ten or twenty rounds indicates a possibility of failure later on, but this is by no means certain to follow. In fact, the more often a given explosive is fired under similar conditions the more certain ought the firing to be with the increased experience, and it seems fairer after the fee is paid to give the applicant his full forty rounds.

The explosive art and science have suffered a severe loss in the death of Colonel Sir Vivian D. Majendie, R. A., K. C. B., Her Majesty's Chief Inspector of Explosives, which occurred suddenly, from heart failure, at Oxford, England, on April 24, 1898.

Sir Vivian Majendie was born in 1836 and entered the Royal

Artillery in 1854. He first saw active service in the Crimean War, in which he won the medal, with clasps, and the Turkish medal, and he achieved further distinction in the Indian mutiny. He became Captain of Artillery in 1861, Major in 1872, and Lieutenant Colonel in 1880, and Colonel (retired) in 1882. He was created Commander of Bath in 1880 and Knight Commander in 1895. He was for ten years on duty at the Woolwich Arsenal and in 1871 was attached to the Home Office as Inspector of Gunpowder Works under the Gunpowder and Nitroglycerine Acts. He was largely instrumental in securing the passage of the Explosive Act of 1875, as his testimony in the Minutes of Evidence and the official and statistical papers he filed, which appear in the Appendix, fill 162 of the large, closely printed pages of the Report of the Select Committee on Explosive Substances appointed by the House of Commons. It was fitting then that after having had so wide an experience and having displayed such thorough acquaintance with the subject, Major Majendie should, on the passage of the Act, have been appointed Chief Inspector.

While holding this office it fell to his lot to examine the bombs, infernal machines and explosives captured by the police, and though he ran serious personal risk, he was fearless in the performance of his duty. It is narrated that on one occasion he carried a rubber bag filled with nitroglycerine, which had been found in the house of a Fenian, in a cab to the laboratory at Woolwich, and that on the way he coolly informed the driver of the danger the latter would run if he did not drive carefully. When the cloak-room at Victoria Station was blown up he opened a clock-work infernal machine found there, though the mechanism was working at the time and the machine might have exploded at any moment.

While his services in the investigation of outrages brought him most conspicuously before the public, his most important service to his country was in so drawing and enforcing the regulations in explosive works as to render employment in these factories among the less hazardous of occupations for British workmen. One of his recent official duties was as a member of the Committee on the Testing of Explosives for Use in Coal Mines, through which it was sought to reduce the hazard in use as well as manufacture, and the week before his death he appeared to give evidence before the Select Committee of the

House of Commons to investigate the danger of low-flash oils. His influence has extended far beyond the confines of his country. For his successful efforts to ameliorate the condition of man he deserves to rank with Davy, Jenner, Francis, Lister and Florence Nightingale. His monument is the twenty-two Annual and fifty Special Reports which bear his signature as Her Majesty's Chief Inspector of Explosives.

His efficiency and tactfulness as an official is testified to by the trade journal, "Arms and Explosives," 6, 126; 1898, which says: "The daily newspapers say nothing of the single-minded thoroughness with which he carried on the daily routine of his work at the Home Office, dealing only, as they do, with the more sensational incidents of his career, when, for instance, at considerable risk to himself, he opened an infernal machine, which, for all he knew, might go off at any moment.

"To those in the explosive trade, however, his ceaseless activity in the duties of inspection, the courtesy and fair-mindedness with which he carried out the stringent provisions of a highly complicated Act, will always remain among the keenest recollections of the past. Sir Vivian Majendie was the very best type of Government official, for he at all times recognized that trade interests must be considered even when departmental authority gave him the best excuse for disregarding such requirements. In no case, however, was the efficiency of his work allowed to suffer, whatever personal sympathies might suggest. He became Chief Inspector of Explosives when the Act first came into existence, and he has continued in office ever since, and year by year his annual reports have shown a steady improvement in the conditions of what was originally a dangerous industry. The precautions which have been elaborated under his care are now such that the death-rate by accident in the entire trade is little more than eight a year, a proportion which will compare most favorably with the ordinary mechanical industries of the country. To judge by experience, one would say that Sir Vivian Majendie was never happier than when carrying on his work, for the indefatigable industry with which he replied to all correspondence, and held himself personally available wherever his presence would be advantageous, was a lesson such as many younger men could with advantage take to heart. Whenever he was approached with a view to the modification of such rules and regu-

lations as seemed to bear with unnecessary hardness upon some section of the trade, he was always ready to receive representations upon the subject, and, wherever possible, he promptly introduced an Order in Council for remedying the ills which had grown up under changing conditions of trade."

The notice alludes to his fondness for photography and his love for children, which was heartily reciprocated by them, and it is accompanied by an admirable portrait which depicts the alert and ever-ready look which was the most prominent characteristic of the original.

The following specifications for smokeless powders for cannon, prescribed by the Ordnance Department, U. S. Army, were issued by the War Department May 12, 1898:

Manufacture.—The manufacture must be open to inspection in all its stages by an inspector designated by the Chief of Ordnance, U. S. A., for the purpose.

Composition.—The powder must be substantially of the composition designated by the Ordnance Department as N N (12.0-25), which consists of one part of nitroglycerine and three parts of nitro-cellulose, containing 12 per cent. of nitrogen, and at least one-third of the nitro-cellulose must be of the soluble variety. A small amount of a suitable neutralizer may be added to insure chemical stability. No departure from the above-stated composition will be made without the approval of the inspector. The ingredients must be of excellent quality and the degree of nitration, as determined by the Lunge nitrometer, close to that prescribed.

Granulation.—The granulation may be of any well-known form, suitable for the use intended, that may be desired by the manufacturer, but must be subject to the approval of the inspector.

Lots.—The powder will be prepared for inspection and delivery in lots, each containing, if practicable, about 10,000 pounds if for a piece of caliber below 8 inches, and about 25,000 pounds if for a piece of 8-inch caliber or over. The exact amount of each lot will be fixed by the inspector after consultation with the contractor. Each lot must be blended to the satisfaction of the inspector.

Inspection.—The inspector will select during manufacture such samples of the ingredients as he may desire to examine. After the lot is blended he will select samples for inspection and proof.

Proof.—Each lot, to be acceptable, must give, with about the charge and under the conditions stated in the following table for the particular case, a muzzle velocity as great as, and a mean pressure not greater than, therein stated, and the chamber pressure must not exceed in any round the pressure stated by more than 2000 pounds.

Piece.	Charge.	Projectile.	Chamber pressure.	Muzzle velocity.
		lbs.	lbs. per sq. in.	f. s.
{ .30-caliber rifle, service	37 grs.	.....	38,000	2,000
{ 3.6-inch mortar, service	6 ozs.	20	17,000	700
{ 3.2-inch field gun *	15.25 ozs.	16.5	32,000	1,450
{ 3.2-inch field gun †	16.6 ozs.	16.5	26,000	1,450
7-inch siege mortar, service	38 ozs.	125	17,000	775
8-inch B. L. rifle, service	70 lbs.	300	35,000	2,250
10-inch B. L. rifle, service	140 lbs.	575	35,000	2,250
12-inch B. L. rifle, service	250 lbs.	1,000	35,000	2,250
12-inch mortar, steel, service	50 lbs.	800	33,000	1,300

* With projectile having band $1\frac{3}{4}$ inches from base.

† With projectile having band $\frac{5}{8}$ inch from base.

NOTE.—For pieces within a bracket the same powder is used.

Stability.—The powder must not be unduly subject to accidental ignition or explosion, or to deterioration under exposure to climatic conditions or in storage. Also, it must withstand successfully the following test: Heated to a temperature of 150° to 155° F., it must not produce any discoloration of potassium iodide starch paper, partly moistened with dilute glycerin, in less than 20 minutes. Chemical and ballistic tests made by the Ordnance Department according to its standard methods will be regarded as standard for the purposes of these specifications.

Delivery and Payment.—The powder will be delivered packed in simple wooden boxes or in packages furnished by the Ordnance Department, at the option of the Chief of Ordnance. All samples selected by the inspector will be delivered at such places as he may designate by the contractor. Payment for each lot will be made on acceptance and delivery, but samples representing rejected lots will not be paid for.

The “Annual Report of the Chief of Ordnance War Department for 1897”* is made up of a summary by the chief of the operations of the department, and twenty-nine separate, illustrated

* Washington, Gov’t Printing Office, 1897, 300 pp., 19 plates.

reports from the commanding officers of the various arsenals and the inspectors of powder and ordnance, which contain much detailed information and record the results of many interesting experiments.

Referring to small-arm ammunition and smokeless powder, General Flagler says the .30-caliber ball ammunition with strengthened case and the blank cartridge with paper bullet have given satisfactory results in service. The expectation that the fired .30-caliber shells turned in from service could be used for reloading has not been realized, as the metal of the case after being fired with smokeless powder becomes brittle. The cause of this in the present shell, which is made of brass (70 copper and 30 zinc), has been traced to the action of the mercury in the primer composition on the metal of the case and particularly on the zinc. The loaded cartridges, when new, can be safely kept as no deterioration occurs until after firing, when the primer is burned and the gases liberated within the case. At present it is expected that a serviceable reloading cartridge will be produced by reducing the amount of mercuric fulminate in the primer, in conjunction, possibly, with the use of an alloy for the cases containing a less percentage of zinc.

Another form of reloading case was proposed by Lieutenant Dunn, the feature of the design being a sliding base sealed with a rubber ring. It is in some respects similar to the Morse cartridge, but differs from it in essential particulars. It offers the advantage of using an alloy, such as so-called gilding metal (93 copper, 7 zinc), which is but little susceptible to the brittleness referred to, but which when made into the present form of solid head case does not possess sufficient strength to resist the high pressures attained in the .30-caliber rifle. The tests thus far made on this case for endurance are favorable and they are now being subjected to storage tests.

Investigations have been made upon the utility of tinning the case of the .30-caliber cartridge for smokeless powder, and the conclusions reached are that under normal conditions of storage brass cartridges do not need protection against erosive action from either black or smokeless powder, but when moisture is present in excess or when the powder has suffered material decomposition, a slight protection, serving at least to defer such action, is afforded by the tin coating, and this, taken in connec-

tion with the neat and distinctive appearance given to the finished product, justifies the use of tinning.

It has been observed that there is a marked tendency to rise and fall of velocity of smokeless powder ammunition depending upon the temperature of the cartridge when fired in the arm, and experiments have been made with the .30-caliber rifle cartridges to determine the changes in velocity for temperatures ranging from -40° to $+130^{\circ}$ F. at intervals of 10 degrees. For this purpose each lot of cartridges was brought to the desired temperature by exposure for twenty-four hours in a chamber having the required temperature and fired. From the data derived from these experiments and from repeated "heat" and "cold" tests previously made in the laboratory of Frankford Arsenal the average results deduced for service ammunition are as follows: The velocity for the .30-caliber rifle varies about 120 feet per second between the limits of temperature given. Taking the standard of 2000 feet per second for a temperature of 70° F. at proof, it diminishes for each 10° fall of temperature by decrements varying from 8 to 3 feet per second, the loss at -40° being about 43 f. s.; and for each 10° rise of temperature it increases from the standard by increments of from 10 to 12 feet per second, the gain at 130° being about 65 f. s.

The Peyton powder at present manufactured by the California Powder Works and the Dupont Company, is now used for the .30-caliber service ammunition, and is satisfactory. In addition to the contracts made with these companies for the supply of powder during the current year, a contract has been made with the Laflin & Rand Powder Company for a quantity to be delivered subject to test, and this company is now experimenting to produce a .30-caliber powder along the lines of its W-A powders. In previous tests this powder has shown excellent ballistic results, but produced undue erosion of the bore of the rifle. It has been found that the endurance of a rifle firing the Peyton powder will readily exceed 5000 rounds, and the specifications for the .30-caliber powder now include a test for erosion, under which "the erosion of the bore, after firing 5000 rounds, must not materially exceed that exhibited by the rifle barrel No. 21,244, which has been fired 5000 rounds and will be retained at Frankford Arsenal as a present standard of reference." It is now also provided that each invoice lot of powder must be thoroughly blended by the manufacturer.

The exposure of service cartridges in shallow open trays to the weather for one year is now systematically pursued and constitutes a most severe test of their keeping qualities. Lots of cartridges made from different invoices of powder are taken from the factory and exposed in this manner, and a portion of each lot is tested at the end of each four months. The tests made with the service powders during the past year confirm those previously reported. Although the loss of velocity from the exposed cartridges was sometimes considerable, the stability of the powder was not decreased, and when heated to 130° F. for twenty-four hours, to ascertain if the powder had been permanently injured, its ballistic properties were restored to nearly the same magnitude as those possessed by the original powder heated to the same extent. The interior of the cases was not injured by contact with the powder during exposure and the primers of the cartridges remained unaffected. Two additional lots of the .30-caliber cartridges charged with Peyton powder and sent to Whipple Barracks, Arizona, for storage, in April, 1895, were returned to Frankford Arsenal after storage periods of twenty-one and twenty-four months. When fired, these gave nearly the same results as those which had been stored for periods of three, six and nine months; in none of which was there any material change from the original quality of the ammunition.

Referring to larger grained powder, General Flagler says it appears conclusive that when nitroglycerine is used under service conditions there appears to be no objection to its employment in powder, but that, on the other hand, there are decided advantages on the score of high ballistics and economy. These conclusions are drawn from general information and from the results of experiments with various smokeless powder compositions, described in his last annual report as being in progress. All these, except those involving long storage, were completed during the year, and the results but confirm the conclusions derived from the earlier and principal portion of the experimental series.

To investigate more fully powders composed essentially of nitro-cellulose and nitroglycerine three compositions of the type designated "N N" (nitro-cellulose, nitroglycerine) were selected as follows:

N N (13-10); nitro-cellulose yielding 13 per cent. of nitrogen, the powder containing 10 per cent. of nitroglycerine.

N N (12-25); nitro-cellulose yielding 12 per cent. of nitrogen, the powder containing 25 per cent. of nitroglycerine.

N N (11-40); nitro-cellulose yielding 11 per cent. of nitrogen, the powder containing 40 per cent. of nitroglycerine.

These compositions were regarded as including the practicable variations within the type, and as producing only allowable erosion and heating effects. As granulation is a mechanical process it was thought best to interest private manufacturers in the solution of this problem, and contracts were therefore awarded to different firms under the above specifications but leaving the manufacturer to choose his form of granulation, it being expected thus to obtain comparisons of the behavior of these different compositions in the several forms of granulation, such as strips, thin squares, tubes and multiperforated grains. Other types than the "N N" are also to be tested and orders have been laid for sample lots of Peyton and "W-A" composition for the 8-inch B. L. R. and of Roltweil composition for the 10-inch B. L. R.

On August 2, 1898, the Navy Department issued the following specifications for U. S. Navy smokeless powder, which is an ether-alcohol colloid of soluble nitro-cellulose, with or without metallic nitrates. The specifications for the ingredients and the solvent are as follows:

I.—INGREDIENTS.

1. *Soluble nitro-cellulose, known as pyro-cellulose.*—It shall contain 12.5 ± 0.1 per cent. of nitrogen, at least 98 per cent. of soluble nitro-cellulose, and less than 1 per cent. of ash, cellulose, and other substances insoluble in acetone. It shall give a heat test at 65.5° C. of at least eighteen minutes, and shall be pulped very fine, all passing a sieve of No. 16 mesh.

2. *Barium nitrate.*—To be entirely free from moisture, ground very fine, all passing a sieve of No. 50 mesh, containing at least 99 per cent. $\text{Ba}(\text{NO}_3)_2$, less than 0.2 per cent. of chlorides (calculated as BaCl_2), and not more than 0.1 per cent. of insoluble material.

3. *Graphite*.—To be chemically pure, containing not more than a trace of silicates or compounds of sulphur.

4. *Potassium nitrate, c.p.*—To be ground very fine and thoroughly dry, of the quality employed in the manufacture of highest grade black powder.

II.—SOLVENT.

1. *Ethyl ether*.—Concentrated, containing no impurities except small amounts of water and ethyl alcohol; clear and colorless; of characteristic pure odor; neutral reaction; specific gravity at 20° C. between 0.717 and 0.723; leaving less than 0.002 per cent. residue after evaporation at 100° C.

2. *Ethyl alcohol*.—92.3 per cent. absolute (by weight). To be clear and colorless; of characteristic pure odor; neutral reaction; leaving less than 0.006 per cent. residue after evaporation at 100° C.

3. *Quantity*.—In case the mixed solvent, composed of 64 parts by weight of ether and 36 parts of alcohol, is supplied by the Department, the weight allowed will be equal to 1.1 that of the finished powder less that of the contained metallic nitrates, and in case alcohol only is furnished by the Department, the manufacturer making his own ether, the weight of alcohol allowed will be 1.4 times that of the finished powder less the contained nitrates.

III.—METHOD OF MANUFACTURE.

1. *Pyro-cellulose*.—No particular method of manufacture is prescribed, provided a material is obtained which conforms strictly to the above specifications. The following method has given satisfactory results at the torpedo station:

Cotton, free from oil and mechanical impurities and containing not over 7 per cent. of moisture, is dipped, in portions of 1 pound each, in 19 pounds of mixed acid contained in an earthenware crock. This mixed acid is composed of about 57 per cent. H_2SO_4 , 28.2 per cent. HNO_3 , and not more than 0.2 per cent. N_2O_4 . The initial temperature of the acid at the time of dipping is about 25° C. The cotton is completely immersed in the acid and held down by an earthenware disk. The crock with its contents is then placed in a trough of warm water, of which the temperature is

about 36°C . At the end of thirty minutes' digestion, the crock is removed from the trough, and the contents turned over with a fork. The crock is replaced in the trough and the digestion is continued for thirty minutes longer. The excess of acid is then removed in a centrifugal wringer and the pyro-cellulose is immersed in a large volume of running water. It is then transferred to a washing centrifugal wringer, where it is washed for fifteen minutes by a stream of water from a hose, being turned over at the end of half this period in order to facilitate the washing. The pyro-cellulose is next pulped at atmospheric temperature in a dilute solution of sodium carbonate, until the requisite fineness is obtained, and is then heated at 70°F . for three hours in a 0.05 per cent. solution of sodium carbonate and washed for three minutes in a centrifugal wringer.

2. *Smokeless powder*.—The finished pyro-cellulose, before the colloidizing, is to be dried or dehydrated until it contains less than 1.5 per cent. of water. The dry ingredients of the powder, consisting either of pyro-cellulose alone, or of pyro-cellulose and a prescribed amount of barium nitrate and potassium nitrate in the proportion of four parts of the former to one of the latter, are to be colloided by means of a solvent composed of 64 parts by weight of ethyl ether and 36 parts of ethyl alcohol, the weight of solvent being at least equal to that of the dry pyro-cellulose. The mixing is to be continued until the material is a perfectly homogeneous mass, free from uncolloided particles. No change in the composition of the solvent or in the ratio of solvent to dry ingredients is to be allowed, unless the product is a perfect colloid of standard toughness. This colloid is to be pressed into powder through dies of such form and dimensions as may be prescribed by the Department for the different calibers. In case the powder is in the form of a ribbon, the drying is to take place between wooden strips, or sheets of blotting paper, or in such other manner as will prevent warping or sufficient distortion to render difficult the loading of the powder into the cartridge case. In the manufacture of small-arm powder, the colloid, in the form of a sheet, is to be cut into flat grains, nearly square in outline, of which the length or width is to be about 2 mm. and the thickness about 0.28 mm. After not less than twenty-four hours' drying, these grains are to be graphited. The finished powder for all calibers shall have been dried at 38° to 43°C . until a sample, heated at

100° C., loses less than 3 per cent. of its weight before an odor of decomposition is noted.

IV.—FINISHED POWDER.

1. *Physical properties.*—(a) The finished powder is to be a perfectly uniform colloid, free from lumps and uncolloided material.

(b) The strips or grains are to be of the standard smoothness and toughness.

(c) The dimensions of the strips or grains are to be in accordance with the specifications of the Department.

(d) The strips or grains shall be of such uniform density that, in a given weight of charge for any caliber, the variation from a mean value in the number of strips or grains shall not exceed 1 per cent.

2. *Chemical properties.*—(a) *Composition.*—The finished powder shall contain not more than 3 per cent. of substances volatile at 100° C., and shall show, by analysis, that its ingredients possessed the requisite properties and were mixed in the prescribed proportions.

(b) *Stability test.*—The finished powder should give a stability or heat test equal to that of similar powder made at the torpedo station, which withstands a temperature of 100° C. for a period of at least ten minutes without discoloring the standard potassium iodide and starch paper.

This test may be made by use of the standard apparatus, with the water bath replaced by a bath of glycerine. The value given above is to be regarded as tentative only, as experiments thus far made have included samples of powder made at the torpedo station only.

(c) *Ballistic properties.*—The finished powder shall give the required velocity within a maximum pressure, the values to be prescribed by the Department for the various calibers.

Bids were opened on September 3 for 1,000,000 pounds of powder made according to these specifications and they reached to 79½ cents per pound.

Under the title "An American Smokeless Powder," *Sci. Am. Sup.* **46**, 18,946-18,947; Aug. 27, 1898, Frederick H. McGahie says, among other statements: "An American powder, the Maxim-Schüpphaus, offers a superior and scientific solution of

the problem whose correctness has been proved by trials and tests extending over the last four years. It is the standard of the United States army, and, after futile attempts to produce a satisfactory powder of their own, the United States navy has lately adopted it.

“The formula employed during its development was 90 parts mixed gun-cotton, 10 parts nitroglycerine, 1 part urea, the nitroglycerine being added principally to insure good ignition. But the M. S. powder is not a definite one. The formula can be varied widely so as to meet all beliefs of ordnance experts.”

It will be interesting to compare these statements with the foregoing specifications and reports.

In the “Report of the Chief of the Bureau of Ordnance to the Secretary of the Navy for 1897,” * Commodore O’Neil says of the work at the Naval Torpedo Station, considerable quantities of gun-cotton and smokeless powder have been manufactured during the past year and researches have been made resulting in the development of a special variety of nitro-cellulose, soluble in ether-alcohol, forming a colloid of extreme toughness, that burns progressively in a very regular manner and which may be converted directly into smokeless powder, decomposing wholly into gaseous products, and possessing a high ballistic efficiency. With the new form of colloid velocities of about 2500 f. s. have been obtained with 5 and 6-inch R. F. guns with pressures of about 16 tons per square inch, and velocities of 2800 f. s. are readily obtainable with the 1-pounder R. F. within the pressure limit of 15 tons per square inch. The powder is quite smokeless.

The problem of the development of smokeless powder may be considered solved, and as the capacity of the factory at the torpedo station is insufficient, orders for 100,000 pounds each have been laid with a firm on the Atlantic coast and one on the Pacific coast for smokeless powder made in conformity with the Bureau’s formula. The deliveries have been made in part and the powder will be issued to vessels in commission so soon as it can be procured and prepared.

The Bureau is of the opinion that for national and economic reasons the Department should own and operate a smokeless-powder factory, at which it could produce a part of the powder

* Washington, Government Printing Office, 1897, pph. 66 pages.

required for the naval service, and an item (\$93,727) has been inserted in the annual estimates for this purpose. The property known as Bellevue Magazine, on the Potomac just below Washington, would be an excellent site, and it is conveniently reached by water and by railroad, and is but two hours' distance from the Naval Proving Ground. The present price of smokeless powder procured by purchase is very high, and the Bureau believes it can produce it in large quantities at a greatly reduced price. The success of the Bureau with its gun factory encourages it to believe that it could do equally well in the manufacture of other munitions of war.

The reserve supply of powder on hand is limited, and no effort has been made to accumulate a large quantity, owing to the uncertain state of the development of powders and because it was believed that the brown powders now in use must soon give way to the improved smokeless powders. A point has now been reached when a satisfactory powder of the latter class has been developed, which is believed to possess excellent keeping qualities and to be superior in every way to the brown powders; and the Bureau recommends that a quantity sufficient to refill all the vessels of the Navy be procured, and with this in view has inserted an item (\$1,000,000) in the annual estimates to begin its accumulation.

Commander Conden, Inspector of Ordnance in charge of the Naval Proving Ground, says the manufacture of a satisfactory smokeless powder has been established, and samples have been tested for all calibers and the powder is now being supplied for all guns up to and including the 6-inch. Powder for the 13-inch B. L. R. was tested in February, 1896, and samples still on hand (September 10, 1897) in the magazine have undergone no change so far as can be judged. The results in all cases are higher velocities with lower maximum pressures than with brown powder, and, coupled with the absence of obscuring smoke, it may be said that the offensive power of every vessel in the Navy will be very sensibly increased by the introduction of these powders. We may congratulate ourselves that we were not led by the apparent difficulties of the situation to adopt the very dangerous nitroglycerine powders that have been very generally adopted in other navies. Our own experience with such powders showed their very dangerous lack of keeping qualities.

Tests have been made of the Gathmann projectile designed to carry very large charges of wet gun-cotton. The essential feature of the projectile is the attempt to use a very thin wall, giving great space for the charge, by equalizing the pressure on the inner and outer surface of the shell. This is done by making the caliber of the projectile considerably less than that of the gun except at the head, where the rifling band is placed and allows free play of the powder pressure upon the outer walls, while a movable piston in the rear transmits the same pressure to the interior walls. A 13-inch tube bored out to 12 inches, fitted with breech-mechanism, chambered to suit the projectiles and rifled for part of the way, and projectiles with walls $\frac{1}{4}$ -inch thick were used, but though the projectiles were filled with inert material they broke up under 6 tons pressure. On increasing the thickness of projectile wall to $\frac{1}{2}$ -inch they stood a pressure of 8 tons and reached a velocity of 1686 f. s. Such a shell loaded with 307 pounds of wet gun-cotton was tested in the gun June 9 with the result that the gun was destroyed, pieces being thrown to more than a mile distance and in every direction.

In connection with these tests experiments were made to determine the effect of the superficial explosion of large charges. Two steel plates, 13 feet by 7 feet by $\frac{5}{8}$ inch, were fixed vertically on the beach 50 feet apart, being parallel to one another and securely braced. The plates were slightly curved and the *curved* (?) sides were toward each other. A Gathmann projectile, containing about 340 pounds of wet gun-cotton, was placed on the beach between the plates, 35 feet from one and 15 feet from the other, and fired by electricity. The explosion was of a high order and locally severe, very small fragments of the shell being found in the vicinity, but the plates remained uninjured, not even being displaced, and no effect of any kind was produced on them. A second Gathmann projectile of the same size, loaded with 220.25 pounds of shell powder, was fired in the same position between the plates with practically the same results except that there were rather larger holes made in the ground. A third Gathmann projectile, containing 307 pounds of wet gun-cotton, was hung against the face of an armor plate standing vertically against a target structure. The plate was 7.5 by 16 feet, 16.5 to 9.5 inches thick and weighed 28 tons, and it had received two test shots for acceptance before this experiment. The shell was

supported on wooden blocks against the middle portion of the plate, so that the whole length of the shell bore horizontally against the plate, and fired by electricity. An explosion of the first order occurred, but the damage to the plate was nil. The face of the plate was fused and burned over a space of 5 feet 10 inches by 8 inches to a maximum depth of $\frac{5}{8}$ inch. The side of the shell next to the armor plate was flattened out and burned into a ragged sheet 5 feet 7 inches by 8 inches. A chicken tied on the ground immediately in the rear of the plate was uninjured; one placed in a cofferdam 50 feet from and in front of the plate was uninjured; one placed in a cofferdam 25 feet from and in front of the plate was killed; one placed unprotected on the ground 43 feet from and in front of the plate was scorched and struck by flying fragments. The abstractor understands that these charges were fired with primers of dry gun-cotton. It is to be regretted that the dimensions of the craters formed were not recorded, as these furnish useful criteria.

Tests of randite for comminution were made by filling a 4-inch wrought-steel common shell with 3 pounds 12.5 ounces of the explosive and firing by electricity in a shed fitted up for the purpose. The explosion was very violent and the shed badly wrecked. In a second test a 4-inch A. P. projectile was charged with 6.7 ounces and exploded with a service single-wire electric primer. The explosion was violent and prompt, and the projectile was broken into many fragments. The explosive seemed very mild and inert when burned in the open air—in fact, difficult to burn—and also very insensitive to shock.

Joveite has been tested at various times during the year as a charge for armor-piercing projectiles with satisfactory results. Some failures were recorded in the early trials, detailed in the last annual report, due to an insufficient igniting charge of black powder in the fuse. Three 6-inch A. P. projectiles were fired through a half-inch steel plate with excellent bursts and break-ups. Two 6-inch A. P. were loaded with joveite on November 24, kept in the magazine until May 6, and then tested with most excellent results, using high pressures, a velocity over 2000 f. s. and a steel plate one and a half inches thick. A 6-inch A. P. projectile was fired with a velocity of 1860 f. s. at a cofferdam protected by a 4-inch nickel-steel face-hardened plate at a point where the cellulose was 4 feet 8 inches thick. The projectile

passed through and exploded about 3 feet in the rear of the cofferdam. A similarly loaded 6-inch A. P. projectile was fired at a cofferdam having a 5.5-inch nickel-steel face-hardened plate on the outside. The shell broke up after passing through the cofferdam, but did not explode. The fuse was recovered and it evidently had failed to ignite the joveite, some of which was in the fuse stock. Portions of the charge of joveite were also found scattered about. A 10-inch A. P. projectile, loaded with 8.75 pounds of joveite, was fired through a 4-inch steel plate on August 28. The explosion took place immediately in the rear of the plate, as was determined by marks of fragments of the projectile in the structure supporting the plate. The results were observed from the launch in the river. The break-up of the projectile was excellent, many pieces scattering along the shore and the surface of the river for a quarter of a mile. The largest fragment found weighed not more than three pounds.

Since the above report was written a 10-inch Carpenter, capped, A. P. projectile loaded with 8.25 pounds of joveite and fused, having a total weight of 523 pounds, was fired with a velocity of 1860 f. s. against a side armor plate of the Kentucky, the impact being at a point where the plate was 14.5 inches thick. The projectile completely perforated the plate and as the fuse functioned properly the projectile burst into a large number of pieces just beyond the plate. There was some slight color from unburned joveite. Ten pieces of the projectile were recovered from the sand having a total weight of 198 pounds, the largest fragment weighing 100 pounds. It was evident from the appearance of the timbers that the explosion took place close to the face of the plate and on the rear side, as no portions of the shell were found on the front side.

In another round a 10-inch semi-A. P. Midvale shell, containing 28 pounds of joveite, of a total weight of 511 pounds and unfused, was fired with 230 pounds of powder against the same plate at a point where it was 16 inches thick. The striking velocity was 1925 f. s. The shell penetrated the plate to a depth of about 12 inches and burst with great force. The plate was thrown down and broken through at all previous cracks. Only one recognizable piece of the shell was recovered, and this was a portion of the base plug which had been sheered off longitudinally and from

which a portion of the screw threads had been entirely removed. This breaking up of the base plug seems evidence of a severe explosion, as in no other case has a base plug been found thus broken.

It may seem proper in this connection to call attention to the article on "High Explosives and Modern War Vessels,"* *Engineer*, December 24, 1897, and *Jour. Roy. U. S. Inst.*, **42**, 475-477; 1898, and to Sir Charles Dilke's† article, republished elsewhere in these Proceedings.

Through the courtesy of Mr. Hudson Maxim, we are in receipt of the following pamphlets containing his work: "A New System of Throwing High Explosives from Ordnance," which is a lecture delivered before the Royal United Service Institution, and reprinted April 15, 1898, from its Journal, in which he describes his invention through which he seeks to provide an aerial torpedo projectile which shall carry a maximum of high explosive with a minimum weight of metal, and at the same time be of such constitution, strength and integrity as to enable it to withstand the shock of acceleration and the pressure of the propelling gun-powder charge, without danger of disruption or distortion of the torpedo or its premature explosion. The torpedo is to be thrown from a light-walled large caliber gun by a charge of Maxim-Schüpphaus torpedo powder, giving a pressure of 10,000 pounds, and to be exploded by a Maxim-Alger fuse. No armor penetration is claimed for the projectile, but the large mass of explosive to be thrown is expected to work havoc.

The second pamphlet is a separate from the *Cosmopolitan Magazine* **25**, 327; July, 1898. It is entitled, "The Engineering Problem of Aerial Torpedoes." The third pamphlet, entitled "Aerial Torpedoes," is reprinted from *Cassier's Magazine* for 1898, and each of these treat of the same subject and traverse much of the same ground as the first, though they are variants.

The fourth pamphlet, reprinted from *Engineering*, June 10, 1898, is entitled the "Maxim-Schüpphaus Smokeless Powder," and deals with the method of producing the multiperforated grain and the manner in which it burns. All these articles are well illustrated and are worthy of examination.

* Proc. U. S. Nav. Inst. **24**, 367-370; 1898.

† Proc. U. S. Nav. Inst. **23**, 740-741; 1897.

We are again indebted to the courtesy of Lieut. W. R. Quinan, superintendent, for the following detailed account of the circumstances attending a recent explosion at the California Powder Works, Pinole, California:

“I have to report that one of our nitroglycerine houses (the new one) was blown up about 1.30 A. M. on the 27th of July, 1898. There were two distinct explosions a few seconds apart. A number of our men went to the scene, manned the fire hose and put out several small fires that started on the site. As soon as it was light enough a large gang of men was put to work to clean up the debris. While they were engaged in this work a second explosion took place (about 5.30 A. M.), which killed four and wounded ten of our men.

The circumstances attending the explosion so far as known were as follows: The house has been in operation since early in June. It was in good order and worked almost perfectly. Since we have been using the Rodeo water we have been bothered somewhat with scums in the waste tanks and in the filters. This is chiefly chalk precipitated from the water by the soda we use in washing. It gives trouble by clogging the filters and making slums in the wash tanks. It holds a little nitroglycerine, and this is so difficult to separate that lately we concluded to throw it overboard rather than let it accumulate. To this end our men have collected it in wash tubs which were periodically taken down to the wharf and dumped. Having some repairs to make to the acid cooling department, which could be best done while running the old nitroglycerine house, we concluded to shut down the new house for a few days and to take advantage of the chance to put in a settling tank for the chalk and to put in a new piece of apparatus, viz., a water-lift, to lessen the labor of the men in handling the slums. The house was accordingly shut down on the 26th (after the work for that day was finished) and cleaned up. The last man of the nitroglycerine gang left the house 3.30 P. M. Attended by Mr. Bermingham, the head carpenter and head lead-burner, I visited the house about that hour to give directions about the changes in the house.

The situation in the house was as follows: All the apparatus, including mixers, separators, drowning tank, wash tanks and waste tanks had been cleaned and washed out. The last charge had been filtered and sent down the flume and the switch broken.

The chalk slums had been collected and put in two wash tubs and mixed with sawdust. (This is done for safety in handling on the cars.) The tubs were placed on a brick pavement in the basement of the building. The only other explosive matter in the building was a little nitroglycerine mixed with acid that always drains back into the blow-cask (a steel vessel to pump with compressed air the waste acid from this building up to the acid cooling house), and a little nitroglycerine held by capillarity in the salt filters on the lower floor of the building. The small amount of unwashed nitroglycerine which the men could not collect and wash in time was sent down to the outside waste tanks about 100 feet away. The house was cleaned up with special care as we wished to put carpenters to work at once in the building. Four of them began operation before four o'clock and worked all the rest of the afternoon.

The amount of nitroglycerine in the blow-cask was unusually small. The foreman, Mr. Graves, an hour after the last charge had been pumped up, gave the cask a second blowing with air. We have used blow-casks over 11 years. We have never had any accident with them except once when a cask was left lying in the hot sun for several days. The basement of this house was cool. The situation was such that it would be a stretch of imagination to suppose a spontaneous explosion either in the cask or in the tubs which contained nothing more harmful than a crude low grade dynamite. However, we have been saved any speculation of this kind. There is indisputable evidence that the explosion was not spontaneous.

Just before the disastrous explosion about 5.30 A. M. a piece of *freshly* burnt fuse about five feet long was found in the shattered lumber which the men were hauling away from the building. Four men testified before the coroner's inquest to the finding of this fuse, which was handed to Mr. Bermingham a few seconds before the disastrous explosion. The conclusion is that some miscreant stole into the house in the dead of night and blew up the tubs. These exploded the blow-cask, which was about eight feet away and above the level of the tubs.

A close examination of the wreck seemed to show that the tubs exploded first; also that the blow-cask was moved from its seat before it went off. There was no crater or disturbance of the ground immediately under its usual seat. The serious dam-

age done was confined to the lower part of the house. The wash tank floor was partly thrown down, two of the three wash tanks toppled over, the roof fell and the filters were covered with miscellaneous debris. The second disastrous explosion came from the filters while the men were working directly over them. The amount of nitroglycerine here was very small. We regain the nitroglycerine by dissolving the salt, so that we can estimate the quantity quite closely. There were not more than ten pounds at the outside and it was scattered through about 400 pounds of wet salt.

Our men in cleaning up the debris acted for the best. They believed there was no danger in working over this and they thought it prudent to clean the place up before the sun came with the heat of day to cause possible trouble. The simplest theory to account for the disaster is that when the blow-cask exploded a little acid and dirt was thrown into the filters and this set up a chemical action which culminated in explosion about four hours afterwards. The stuff being brought to the critical point may have been set off by a slight jar, but in regard to this it is useless to speculate. Under ordinary conditions I do not think a fulminate cap would have exploded it.

There is one more point to be noted. The tubs (ordinary wooden wash tubs) were old dynamite carriers and held a lot of nitroglycerine absorbed into the wood—about 12 or 15 pounds each, taking the gain in weight as a criterion. It was this that did most of the damage to the building and not the mixture of scum and sawdust. The amount of nitroglycerine in the latter probably did not exceed five pounds and there was such a large admixture of sawdust it was barely explosive.”

“Explosive Materials.”* The phenomena and theories of explosion and the classification, constitution, and preparation of explosives, by John P. Wisser. This book is issued as No. 70 of Van Nostrand’s Science Series, but it must be remembered by bibliographers that it is a distinct work, as the original contained a translation of Berthelot’s *Lecture on Explosive Materials*, by Dr. Marcus Benjamin, a translation of Braun’s *Historical Sketch of Gunpowder*, by Lieut. John P. Wisser, and a *Bibliography of*

* New York, D. Van Nostrand Company, 1898, sm. 8vo., 160 pp.

Works on Explosives, by Mr. W. H. Farrington. The first edition having become exhausted, it became necessary, in order to keep the series complete, to issue a new edition, but as, in the fifteen years which have elapsed since the appearance of the first edition, many changes have taken place in the views held regarding the phenomena of explosions and many new explosives have been produced, particularly the important class of smokeless powders which have attracted attention, it was deemed best to have the book rewritten, and this work was wisely put into the hands of Captain Wisser. The subject-matter of the present volume is based on the original essay of Berthelot, but the theories set forth by him are modified by those that have been formulated by Cooke, Abel, Threlfall and Mendeléef, and Captain Wisser has blended these into a most lucid presentation of the subject as now most generally accepted. In addition to this, Captain Wisser has given sufficiently clear descriptions of a large number of explosives and of the processes of manufacture of the more commonly used ones to satisfy the needs of the average reader or military man. In fact, it is surprising that he has been able to put so much information into a "pocket volume." It is to be regretted that the publishers have not given the work a setting equal to its merit and that many of the pages should be distinctly offensive in their make-up. The book ends with an ample index.

"Manual of Military Field Engineering,"* for the use of officers and troops of the line, by William D. Beach, is the second edition of a work by Captain Beach in the revision of which he has collaborated with Lieut. Root and Lieut. Slavens, and which has been approved by the Secretary of War for special study by officers of the army subject to examination for promotion. Upwards of twenty pages of the book and three plates are devoted to the use of explosives in military demolitions. The usefulness of the book would be improved by a table of contents.

"Scientific American Army and Coast Defense Supplement" † is a collection of articles on gun, projectile, armor and explosives which have appeared from time to time in the Scientific

* Kansas City, Hudson-Kimberly Publishing Co., 8vo, 1897, 282 pp., 60 plts.

† New York, Munn & Co., 1898, 1g. 8vo, 64 pp., 110 Ill.

American and Scientific American Supplement, and which were believed to be of popular interest during the war. The articles are of varying merit and accuracy, but the cuts are attractive.

“Lectures on Explosives,” * by Willoughby Walke, is the second revised and enlarged edition of a course of lectures prepared in 1891 especially as a manual and guide in the laboratory of the U. S. Artillery School at Fort Monroe, and which has now been officially adopted for the examination of officers of artillery for promotion in the corps. The work is well arranged and published in good form.

“Notes on Cordite” † is the title of a trade circular issued by Kynoch, Limited, of Birmingham, England, which contains excellent cuts of the Lion Works at Wilton, the cordite and nitroglycerine works at Arklow, Ireland, machinery for blending cordite, cartridges of cordite for different calibers and other cuts. The pamphlet treats of the relations of smokeless powder to gunpowder, describes in general terms the manufacture of smokeless powder, dwells upon the question of the sensitiveness of smokeless powders to climatic changes, and states that cordite has been proved, both in India and Canada, to have maintained the same velocities and pressures as at the test ranges at home. Referring to the objection that the heat it develops tends to erode the barrel of a rifle, it is claimed that an ordinary .303 magazine rifle will fire 10,000 rounds of cordite without becoming unserviceable. Also it is stated that the conditions under which cordite is accepted by the British Government do not allow an extreme variation between the maximum and minimum velocities of the projectile greater than 40 or 50 feet per second in a speed of 2300 feet per second, and that in practice the mean deviation usually does not exceed 10 feet. Tables are given for the charges, muzzle velocities and steel plate penetration with cordite for each of the calibers from .303 rifle up to 6-inch Q. F., and comparison is made with gunpowder for five of these calibers, but no mention is made of pressures.

* New York, John Wiley & Sons, 1897, 8vo, 435 pp.

† Wilton, Birmingham, Kynoch, Limited, no date, 4to, 22 pp., 13 Ill.

Arms and Explosives **6**, 40; 1897, reviews "Des poudres pyroxylin pour fusils de chasse." * Quelques mots de réponse au résumé de la conférence donnée le 18 Janvier 1897 par M. Jules Polain. By Henri Quersin.

The *Revue d. Artil.* **51**, 608; 1898, announces "Treatise on Service Explosives" † (official) and "Regulations for Magazines, Ammunition Stores, Laboratories," etc.‡ (official); also in **52**, 196; 1898, "La plastoménite," § by General Wille.

* Brussels, Paul Lacomble.

† London, Eyre & Spottiswoode, 1895, 8vo, 126 pp.

‡ London, Eyre & Spottiswoode, 1894, 8vo, 190 pp.

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INDEX
TO THE
LITERATURE OF EXPLOSIVES

PART I.

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BALTIMORE:
ISAAC FRIEDENWALD.
1886

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*Press of Isaac Friedenwald,
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This index is intended to embrace not only such articles as treat of the composition and of the chemical and physical properties of explosive substances, but also of their manufacture and use in the arts. This part contains the titles of papers appearing in such periodicals as the indexer has been able to review from the date of first issue. 442 volumes have been thus reviewed for this part. Many other titles of papers have been collected, but the indexer has not yet had access to complete sets of the periodicals from which they have been gathered. A large number of titles of separate publications, treatises, text-books and the like have also been collected. It is hoped that it will be possible to eventually publish these, together with a "subject" and "author's" index to the entire list.

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TO THE

LITERATURE OF EXPLOSIVES

PART II.

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BALTIMORE:
DEUTSCH LITHOGRAPHING & PRINTING CO.
1893

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Press of
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I desire here to acknowledge my indebtedness to Mr. M. M. Ramsey for his very valuable assistance in reading the proof.

COLUMBIAN UNIVERSITY,
WASHINGTON, D. C.

April, 1893.

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- Prinzhorn, H. Composition of matter for fuel. (Charcoal, sodium and potassium nitrates or other soluble hyperoxide, glue, dextrin, gum arabic or other adhesive material, clay and iron-filings.) 8, 242. *U. S. Pat.*, No. 352889, November 16, 1886.
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- Volney, C. W. Explosive compound. (Solution of nitro-starch in nitroglycerine.) 9, 158. *U. S. Pat.*, No. 366281, July 12, 1887.
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- Emmens, S. H. Explosive derived from phenol. (New crystallized product obtained by action of hot fuming nitric acid upon picric acid in excess.) 10, 48. *U. S. Pat.*, No. 376145, January 10, 1888.
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- Broncs, B. Explosive compound. (Consists of a double salt of sodium picrate with other picrates, potassium nitrate, saccharine matter, a gummy or resinous substance and soot.) **12**, 51. *U. S. Pat.*, 421662, Feb. 18, 1890.
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Abel, F. A. Gelatinous explosive. (Nitroglycerine and nitrocellulose to which tannin is added to impart a propulsive character to the explosive.) **12**, 125. *U. S. Pat.*, 425648, Apr. 15, 1890.

Germain, P. Dynamite. (Uses spongy vegetable matter for a dope.) **12**, 178. *U. S. Pat.*, 427679, May 13, 1890.

Quinan, W. R. Mixer for explosives. **12**, 179. *U. S. Pat.*, 427707, May 13, 1890.

Todd, E. N. Process of manufacturing thin sheets of nitrocellulose. **12**, 236. *U. S. Pat.*, 428654, May 27, 1890.

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CORRIGENDA.

Page 546, line 24, for *dynamite* read *dynamic*.

Page 588, line 5, the sentence should read: *A foot-pound is equal to twelve pound-inches, or twelve thousand pound-thousandths-of-an-inch.*



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U. S. NAVAL INSTITUTE, ANNAPOLIS, MD.

CRUSHER AND CUTTER GAUGES FOR EXPLOSIVES.

BY W. R. QUINAN, MEMBER U. S. NAVAL INSTITUTE.

The subject of explosives is one upon which we need light. Though in the last two decades we have made some progress in their study, our theories are still disjointed and incomplete. The first assured step in this progress, as indeed every subsequent step, has been gained by subjecting explosives to scientific tests and measurements. Means of measuring mass, time and space have been the three agents of progress. One of the recent contributions to this good work is a paper by Lieutenant Willoughby Walke, 2d Artillery, instructor in charge of the U. S. Artillery School Laboratory, published in the *Journal of the American Chemical Society*, Vol. XII, No. 7, Sept. 1890. This paper, whatever may be its defects, has the merit of being perfectly impartial. Lieutenant Walke has no particular explosive to exploit. It is to be hoped that he will continue his investigations. In making his experiments he "decided to use the Quinan pressure gauge, both on account of the degree of accuracy with which it registers the pressure, and because of the ease with which the apparatus is manipulated."

In the description which originally presented this instrument to the public, no originality was claimed for it. The apparatus in other forms had been used by other experimenters. So far as I know, the first description of such an instrument used for testing high explosives was published by the late Henry S. Drinker (see "Tunneling, Explosive Compounds and Rock Drills," page 77); so if there is any credit due, it should go to him. Especially so, since with this instrument he demonstrated beyond a doubt the cardinal principle of modern dynamites, viz., that an explosive dope adds materially

to the force of nitro-glycerin, a fact which had been disputed by Mowbray and received no countenance from Hill, Trauzl or André (see pages 71 and 72).

Out of deference to Drinker, my apparatus was called also a "pressure gauge." The better term, "crusher gauge," will hereafter be used.

The Drinker gauge can be succinctly described in his own language as follows, omitting the references to the drawing: "A third apparatus was tried, which we will term a pressure gauge. It consisted, as shown in the figure, of a vertical steel pin $6\frac{3}{4}$ inches long, $1\frac{1}{2}$ inches in diameter, enlarged at the top to 4 inches. This pin weighed $8\frac{1}{2}$ pounds, and it slid vertically (through a hole) in an iron block, which block was bolted to an iron foundation weighing some 1200 pounds. The pin rested upon a small truncated cone of lead which itself rested upon the foundation." We will add that the block was recessed under the pin so that the lead plug could be manipulated; also that the top of the pin (or piston) was flat, and the *shot* had a recess or cavity to make room for the charge.

The objection to Drinker's gauge for regular work is that the piston is too light, and gets jammed by upsetting. There is also some risk, as the explosive is not confined by a cavity in the piston, but is liable to get scattered on the flat surface. Liquids cannot be tested at all.

The following description of the Quinan gauge is republished, so that the discussion which follows may be intelligible to the general reader.

PRESSURE GAUGE.

"Guided by this reasoning I was lead to adopt, as my test for the higher grades, the instrument misnamed the 'Pressure Gauge,' in which the force of the powder is measured (indirectly) by the compression of a plug of lead. I do not pretend to any originality in this apparatus, as similar instruments have already been used for this purpose. (See Drinker on *Tunneling*, page 77.) The particular form, however, devised by me, having been tried by many hundred experiments, and having proved satisfactory in every respect, merits, I think, a detailed description.

As shown in the drawing (Fig. 1), it consists of a heavy block of wood, upon which is bolted a cast iron block or base. In this base are inserted four wrought iron guides, or standards, set around

the circumference of a four-inch circle. The lead plug rests upon a steel disc (not apparent in the drawing), which is let into the iron block flush with its upper surface. A ring holds the guides in place at the top, their ends being reduced to screw-bolts, passing through the ring, which is held down by nuts.

The piston (Fig. 2), which is the piece resting on the plug of lead, is a cylinder of tempered steel, four inches in diameter and five inches in length. It is turned away at the sides to lighten it as much as possible. It moves freely between the guides. In the top is a parabolic-shaped cavity to hold the charge of powder. The weight of the piston is twelve and one-quarter pounds.

The shot (Fig. 3), made of tempered steel, is four inches in diameter and 10 inches in length, weighing thirty-four and a half pounds. It is bored through its axis to receive a capped fuse.

To operate the instrument, a plug of lead is placed upon the steel plate within the guides. The piston is put down gently upon it, and the charge of powder placed in the cavity. The shot is next lowered gently upon the piston, and the capped fuse pushed down through the hole in the shot. The fuse being lighted, when

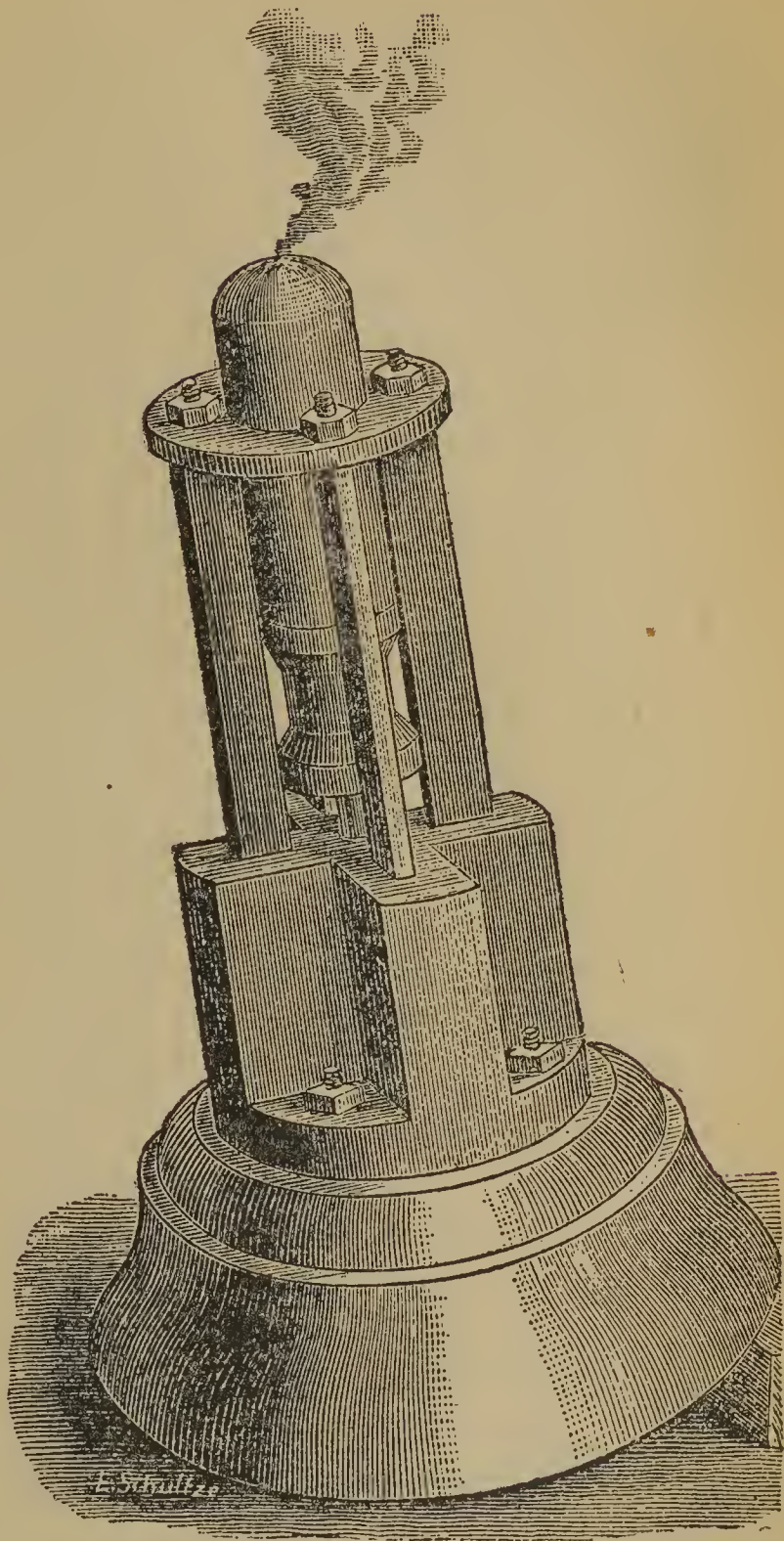


FIG. 1.—Pressure Gauge.

the fire reaches the cap the charge is exploded, throwing out the shot and compressing the lead plug. The accuracy of the test is

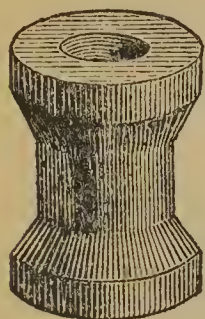


FIG. 2.—Piston of Pressure Gauge.

based upon the assumption that the lead plugs shall be of uniform density and homogeneous structure. The form of plug adopted was a cylinder, one inch in diameter, and one inch in length (Fig. 4).

In regard to the kind of plug, my choice lay between plugs cast in molds, and plugs cut from a solid bar, which could be obtained of the desired dimensions in the factories.

This lead bar, though not made of perfectly pure lead, is manufactured from large masses of metal, is very dense, and can be obtained in lengths of 50 feet. It seemed to me that the desired uniformity would be more likely to obtain in this product than in plugs cast, one at a time, from small masses of metal. Having prepared plugs of both kinds, the next point was to test their relative merits for my purpose. The nature of this test was fixed by an additional and independent consideration. It should be borne in mind that while being compressed by the explosion in the pressure gauge, the density of the plug as well as the lead surface opposed to the piston continually increases. It is plain from this that the amount of compression shown by the plug is not a direct measure of the strength of the powder. For illustration: if one powder, exploded in the pressure gauge, compresses a plug $\frac{250}{1000}$ of an inch, and

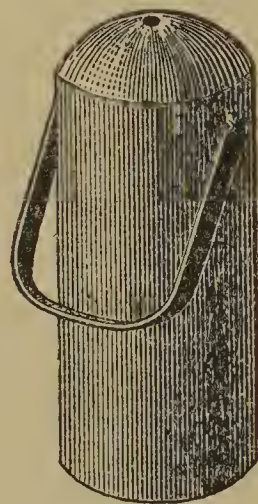


FIG. 3.—Shot of Pressure Gauge.

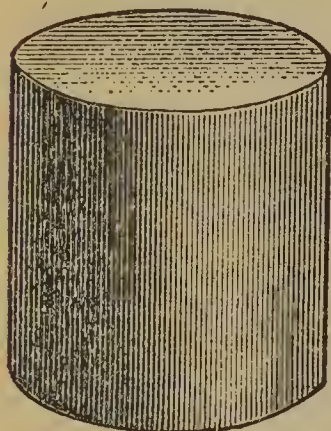


FIG. 4.—Form of Lead Plug used in Pressure Gauge, Full Size.

another powder compresses a plug $\frac{500}{1000}$ of an inch, the latter powder would be twice as strong as the former if the compressions were direct measures of relative strengths. But in fact the latter powder is more than twice as strong. The problem was, how much. As a practical measure of the strength, I assumed it proportional to the *work* performed in reducing the height of the lead plug. To get an expression for the work, it was only necessary to find the number of foot-pounds required to produce the different amounts of compression. Acting upon this reasoning, an apparatus was built as shown in Fig. 5.

It consisted of three boards, so connected as to form a slide sixteen feet high, in which a weight (the shot of the pressure gauge) could fall freely. One of the boards was graduated into feet and half feet. The horizontal board at the bottom, upon which the others were nailed, rested on a heavy post set deep in the ground. A round tenon formed on the top of the post projected through a hole in the board. On the top of this tenon, turned bottom upwards, was placed the piston of the pressure gauge. This served as the anvil, and on it the plugs were placed. The fuse-hole of the shot was plugged with a large wire, which projected through the top and gave a hold for a simple form of clutch, by means of which and a light rope passing over a pulley at the top of the structure, the shot was hoisted to any desired height. The clutch was released by hand from the steps of a ladder.

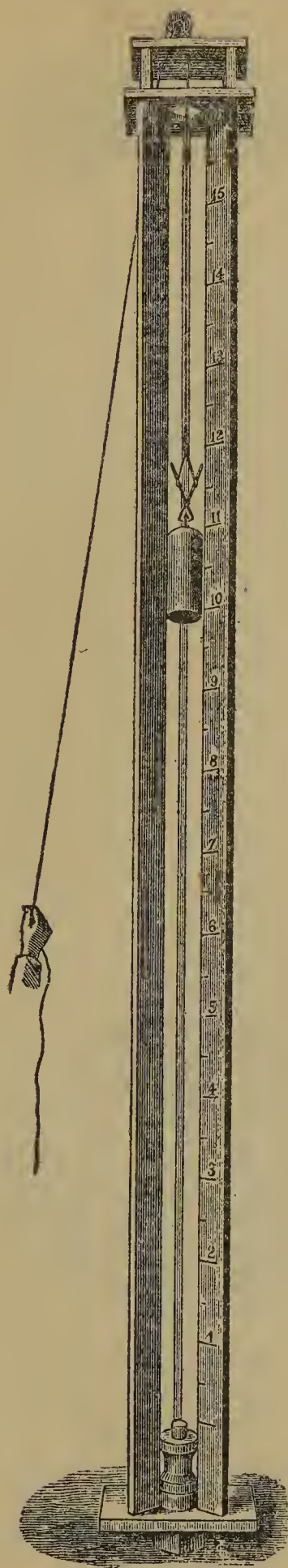


FIG. 5.—Foot-pounds Machine

My first work with this apparatus was to test the uniformity of both kinds of plugs. In selecting the cast plugs for test, they were carefully weighed, and all above or below a certain standard, as well as those showing any signs of flaws or other defects, were rejected. The first half-dozen blows upon the cast plugs showed such anomalous results that I rejected the whole batch, and molded a new lot, hoping by varying the method to obtain more homogeneous castings. The experiments with these, however, were far from satisfactory.

Turning next to drawn plugs, I had the satisfaction of finding them remarkably uniform. The plugs were carefully measured before compression and again after compression, by taking the average of several measurements. The difference between the original length and the reduced length gave the compression caused by the blow of the shot in falling.

The instrument used in measuring the plugs is the micrometer calipers, manufactured by Brown & Sharp (shown in the drawing Fig. 6).

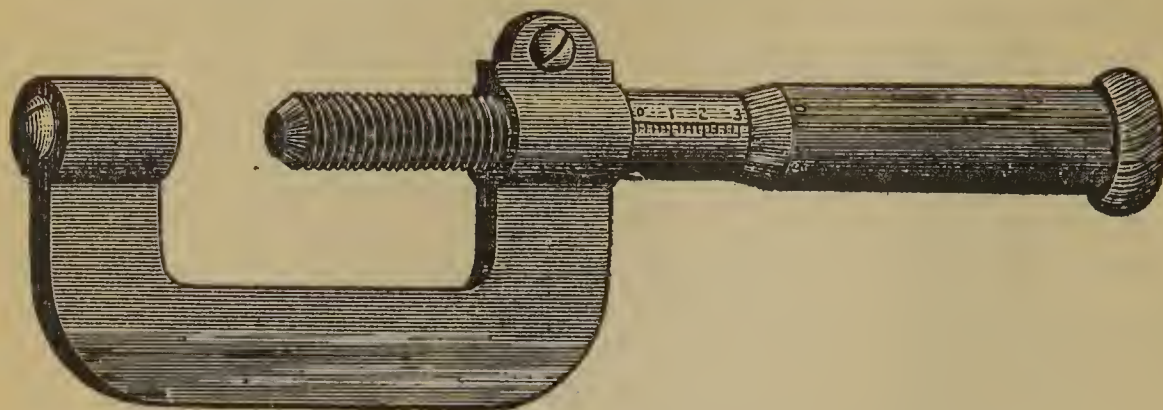


FIG. 6.—Micrometer Calipers for measuring Lead Plugs.

It is exceedingly accurate and convenient, and reads to the thousandth part of an inch, and even this space can be readily divided. The more uniform structure of the drawn plugs as compared with

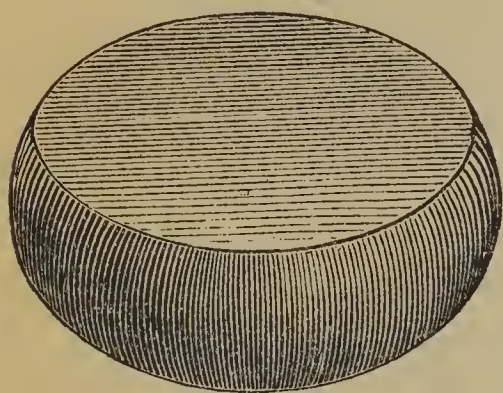


FIG. 7.—Drawn Lead Plug after compression.

the cast is apparent in the different appearances of the two after reduction in the pressure gauge or in the foot-pounds machine. The drawings (Figs. 7 and 8) show this better than description. Having adopted the drawn plugs, I proceeded to construct a table for converting the compressions of the drawn plugs into foot-pounds, or actual measures of the strength of powder.

This was simply and expeditiously done by making several series of experiments in dropping the shot from various heights, beginning with a half foot and going up a half a foot at a time to about sixteen feet. An average of all the compressions at a given height was assumed as correct. The height multiplied by the weight of the shot gave the foot-pounds corresponding to that particular compression.

To more graphically represent the relations between the plug compressions and foot-pounds, as well as for convenience in my work, I constructed a diagram, using the compressions as the ordinates, and the foot-pounds as the abscissas of a curve.

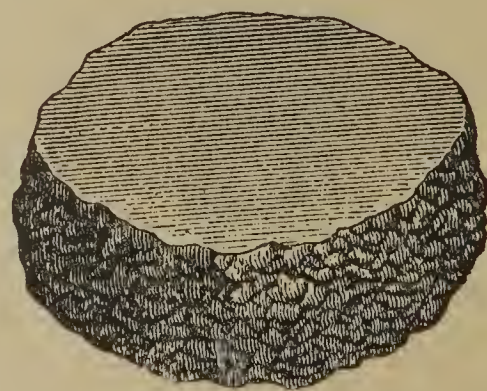


FIG. 8.—Cast Lead Plug after compression.

The extreme co-ordinates were fixed by nitro-glycerin.

This diagram, 21 x 14 inches, has been relied upon for converting plug compressions into foot-pounds, or units of strength. My standard charge for the pressure gauge is 24 grains."

The diagram referred to, together with the original record of the experiments with the foot-pounds apparatus, was destroyed by fire in my laboratory several years ago. However, the curve will be found very accurately reproduced in the dotted line on Plate I.

When Lieutenant Walke was preparing for his experiments he wrote to me for a copy of the diagram or table from which it could be constructed. At that particular time I could not furnish the required data. Since then I have got possession of my note books in which I had recorded several hundred plug compressions by different explosives (covering the whole range of the curve) with the corresponding foot-pounds taken from the diagram. These have enabled me to replot the curve very accurately. Of course there were some mistakes among these co-ordinates, but the error was generally so large as to leave no doubt about the propriety of rejecting it in constructing the curve.

In using the crusher gauge for testing high explosives I have assumed that a given compression of a lead plug denotes exactly the same amount of work, whether the compression be caused by a falling weight or by an explosive—not a very violent assumption, and yet I doubt if it is strictly true. However, we are not prepared to discuss this point just now.

Comparing great things with small, it is a satisfaction to know that General Abbot, working independently upon the same subject, adopted the same material—lead—to record the action of his explosives, and determined the foot-pounds corresponding to plug compressions in substantially the same way. He used the blow of a swinging pendulum for this purpose. For his unit, however, he adopted *intensity of action*, which he defines as the mean pressure, to obtain which he divides the foot-pounds representing the kinetic energy or work of the pendulum hammer by the path described by

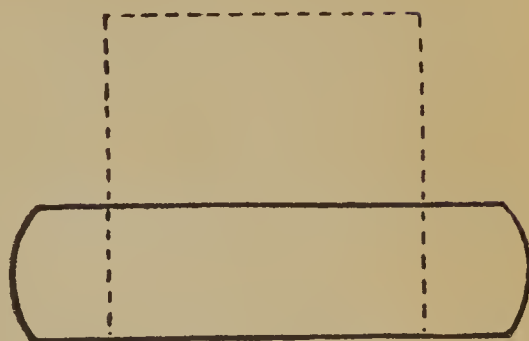



FIG. 9.—Section of Plug showing reduction in Pressure Gauge.

the point of application of the force in its line of direction ; that is, he divides the work expressed in foot-pounds by the plug compressions expressed in feet to obtain the mean pressure in pounds. He used lead plugs of different sizes, which gave different paths for the same work, and, consequently, different mean pressures for the same force. To overcome this difficulty, he decided to translate his energies into mean pressures by adopting the indentation of Rodman's pointed indenting tool into discs of copper as the uniform path to be used (see page 26 of his "Report on Submarine Mines").

General Abbot's problem was much more difficult and intricate, in that the blows of his explosives were transmitted through water, and the law of variation in energy and intensity with weight of the charge, depth of submergence, distance and angle of direction, had to be determined, while a host of minor conditions had to be dealt with and disposed of.

His methods, in my opinion, are beyond criticism. Thoroughness in practical experimentation is supplemented by equal thoroughness in analysis. No labor is shirked, no guessing is indulged in, no short cuts taken to doubtful conclusions. The task imposed was herculean ; its accomplishment has a singular completeness and definition. The Report is a model of careful and accurate work in a new field.

LAWS OF COMPRESSION OF CYLINDRICAL LEAD PLUGS.

We return to a consideration of the curve on Plate I (see broken line), which gives the relation between plug compression and the corresponding work in foot-pounds for a certain kind of cylindrical one-inch lead plugs. This curve was constructed from experiments with the foot-pounds or falling weight machine. The plugs compressed in this way were remarkably uniform in appearance. Figure 7 (page 512) gives a good general idea of their shape. Now, in examining a variety of plugs *compressed by explosives*, I have made certain general observations, as follows : For moderate compressions the plug remains a true cylinder ; this form holds good up to a compression of about .200". For higher compressions, say up to .400", the plug departs more and more from this form and becomes barrel-shaped. At still higher compressions it becomes tub-shaped—large end up—sides slightly rounded, thus  ; at .600" this form is quite marked.

The retention of the cylindrical form for even moderate compres-

sions is rather remarkable, and shows that the flow of the metal is equal in all the horizontal layers.*

It occurred to me that the change of form might be due to or, at least, accompanied by a corresponding change of density, and that the density for small compressions might be sensibly uniform. I therefore weighed in air and water five plugs. One was of original full length as cut from the bar, the others had been subjected to various degrees of compression up to .670". The first was a true cylinder, one inch in diameter, the next was a cylinder of greater diameter, the next two were barrel-shaped, and the last was a flat disc $1\frac{3}{4}$ inches in diameter across the top, with a decided tub shape.

The original lengths varied from .983" to .992". The results were as follows:

	Wt. in air. Grammes.	Wt. in water. Grammes.	Sp. gravity.
1. Original plug,	144.45	131.76	11.383
2. .159" compression,	143.78	131.15	11.384
3. .305" " "	144.95	132.22	11.386
4. .409" " "	145.11	132.37	11.390
5. .670" " "	145.09	132.37	11.406

Although the scales were not delicate enough for very fine work, a law of change in density is clearly shown, and, so far as the evidence goes, it disproves my assumption that the density remains constant for small compressions. I was led, however, by this erroneous assumption into the following speculations, part of which are certainly more curious than useful, but may, nevertheless, be of interest. If we assume that the density remains the same, and that the plug retains the cylindrical form throughout (which is not very far from being true), the relation between compression and work can be readily deduced, for the resistance will then be directly as the area of the surface pressed, and the volume being constant this area will bear a simple relation to the compression.

Let y = compression.

L = original length of the plug.

$L - y = z$ = reduced length of the plug.

A = area of top of the plug.

* The same remark applies to the small copper cylinders used by ordnance experts for taking powder pressures in guns. Those that I have seen preserve the cylindrical form very accurately for moderate compressions, either by powder or by a falling weight.

V = volume—constant.

K = a constant—the resistance per unit of area.

R = variable resistance.

x = work of compression.

Then $R = A K$, and since $Az = V$,

$$R = \frac{KV}{z} \text{ or } Rz = KV,$$

which is the equation of a hyperbola referred to its center and asymptotes.

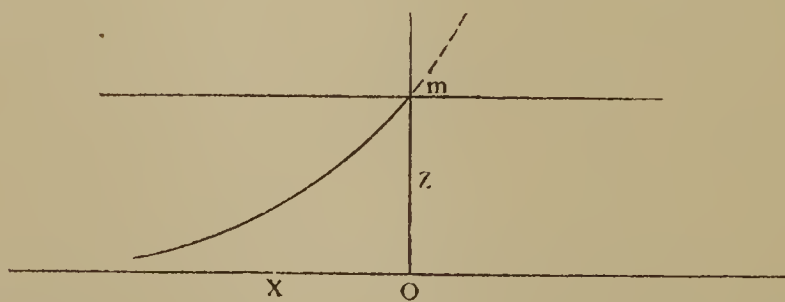
For simplicity we assume the asymptotes to be at right angles to each other. Then since

$$x = \int R dz = \int KV \frac{dz}{z},$$

we have $x = KV \log z + C$, x being the area included between one branch of the hyperbola and the asymptotes.

If we call L —the original length of the plug—unity and make this the ordinate of the vertex from which to estimate the area, we have $Z = 1$, $KV = 1$, $C = 0$; whence $x = \text{Napierian log } z$. That is, the work of compression is the Napierian logarithm of the reduced length of the plug when the original length and the resistance at the beginning are each considered unity. z being less than unity, x will be negative, and we consider only that part of the logarithmic curve to the left of the axis of z , or axis of numbers.

The curve, like all logarithmic curves, crosses the axis of numbers at the distance unity from the origin, and, since the



modulus is unity, it crosses at an angle of 45° —the modulus being equal to the subtangent on the axis of logarithms. The axis of x is an asymptote to the curve.

To express the equation of the curve in terms of y , we transfer the origin to the point m , which gives $x = \text{Napierian log } (1 - y)$.

This value for the work is expressed in terms of the length of the plug and of the primary resistance, each taken as unity, and is not directly comparable with *foot-pounds*.

To make such a comparison we must assign a modulus to the system of logarithms which is perfectly legitimate on other grounds, since we could have referred the original equation of the hyperbola $Rz = KV$ to asymptotes which were oblique to each other, in which case the sine of the angle included by them would have become the modulus of the system.

In selecting a modulus we have a small latitude. Properly we should take a modulus which would cause the logarithmic curve to make the same angle with the axis of y or z , as does the actual curve constructed from experimental data. Determining this angle would depend upon the accuracy of the construction. We can arrive at nearly the same thing by assuming the curves coincident for small values of y .

Following is a table of values of x (corresponding to the assumed values of y) deduced from the equation, $x = \log (1-y)$ and also from $x = .234 \log (1-y)$, the minus sign of x being omitted.

$y = \text{compression.}$	$x = \text{work.}$	
	$m = 1$	$m = .234$
$y = .050$	$x = .051$	$x = .012$
$y = .100$	$x = .105$	$x = .025$
$y = .200$	$x = .223$	$x = .052$
$y = .300$	$x = .356$	$x = .083$
$y = .400$	$x = .511$	$x = .120$
$y = .500$	$x = .693$	$x = .162$
$y = .600$	$x = .916$	$x = .214$
$y = .700$	$x = 1.204$	$x = .282$

In plotting the logarithmic curve corresponding to the modulus .234 for comparison with the experimental curve, since y expressed in thousandths of an inch is taken as a whole number, the values of x must be multiplied by 1000 also, or the numbers in the last column above taken as whole numbers. The curve will be found on Plate I.

For plugs of one inch diameter we see that there is no close agreement between the logarithmic curve and the actual. But the former was deduced under the assumption that the density remained the same and that the plug retained the cylindrical form, neither of which propositions is true. It will hereafter be shown that for plugs of smaller diameter the agreement of the logarithmic curve with facts is closer, but we will now try to deduce a form of equation which is

more flexible than the logarithmic and better adapted to represent the relation between work and compression. It is true we cannot apply the same rigid course of reasoning in deducing it, but the result seems to be reliable for practical use.

As to the general form of the equation: first, it must be such that the curve passes through the origin—that is, it has no absolute term; second, it must be concave towards the axis of x ($\frac{dy}{dx}$ a decreasing function of x); third, L being the original length of the plug, a line parallel to the axis of x at distance L must be an asymptote to the curve.

The simplest equation to fulfil these conditions that has occurred to me is

$$x = \frac{y}{L-y} \text{ or } y = \frac{Lx}{1+x};$$

in fact, it is too simple for our purpose. It is probable that y needs both a coefficient and an exponent to represent the curve. Giving y a coefficient B , we have

$$x = \frac{By}{L-y}, \text{ in which } L = 1000.$$

Testing this by applying it to the dotted curve of Plate I, we determine the value of B from some of the co-ordinates taken from the curve, as follows:

Foot-pounds.	Comp. $\frac{1}{1000}$ inch.	
$x = 30$	$y = 100$	$B = 270$
$x = 80$	$y = 200$	$B = 320$
$x = 145$	$y = 300$	$B = 338$
$x = 233$	$y = 400$	$B = 349$
$x = 356$	$y = 500$	$B = 356$
$x = 430$	$y = 550$	$B = 352$
$x = 530$	$y = 600$	$B = 353$

The only glaring anomaly in this table is $B = 356$, which, it is plain to see, results from the flattening of the curve about this point. We conclude, however, that B is not a constant, as it should be if the equation were adequate, and that y needs an exponent greater than unity. The equation then becomes

$$x = \frac{By^a}{L-y};$$

L in this particular case being 1000.

I determined a number of values of a and B by using the values of x and y , given above, taking them in sets of two. This process gave values for B ranging from 160 to 210, and corresponding values for a from 1.2 to 1.05. Each set of these, applied to the equation above, determined a curve agreeing more or less closely with the dotted one and coinciding with it in at least two points. I finally selected as the best values those in the following equation:

$$x = \frac{190y^{1.1}}{1000 - y},$$

and the full curve in the plate is constructed from this.

The following short table of co-ordinates gives a comparison of the values of x as taken from the dotted curve (or rather from one drawn previously on a larger scale), and the values of x calculated to the nearest whole number from the above equation:

Compression in $\frac{1}{1000}$ inch.	Foot-pounds, dotted curve.	Foot-pounds, computed.
y .	x .	x .
50	12	15
100	30	33
200	80	81
300	145	144
400	233	231
500	356	354
600	530	540

By means of this table the plotting of both curves on Plate I can be checked. The plotting is not perfectly accurate. Except at the extremities the agreement of the two curves should be closer than shown by the plotting.

We can also deduce a general equation of the form

$$x = \frac{By^a}{L - y};$$

in this rather clumsy way: If in the equation

$$R = \frac{KV}{z} = \frac{KV}{L - y},$$

we assume R to be the *mean* resistance corresponding to the compression y , K and V having suitable values, we have the following simple expression for the work,

$$x = \frac{KVy}{L - y}.$$

But K and V are no longer constants. V , the volume, diminishes slightly as y increases. Its particular value in this equation corresponds to some fractional part of y . K , the resistance on the unit of area, increases as y increases, but its value also corresponds to some fractional part of y . The product KV is, therefore, a function of y , probably of the form $CKVy^b$, in which C is a constant, K and V have their *primitive values*, and b is a fractional *exponent less than unity*. Substituting this for KV in the equation above, omitting C , and placing $1 + b = a$ for a new exponent, we have

$$x = \frac{KVy^a}{L - y},$$

as our general equation for cylindrical lead plugs, in which

x = work expressed in foot-pounds,

y = compression expressed in $\frac{1}{1000}$ of an inch,

L = original length of the plug expressed in $\frac{1}{1000}$ of an inch,

V = original volume of the plug,

K = constant depending on the nature of the lead,

a = number between 1 and 2.

The only other recorded comparison of the compression of lead plugs with the work required to produce them, that I know of, is given in General Abbot's Report (page 22). His plugs were all made from a single lot of lead selected at the Rock Island Arsenal. They were made by casting and compressing in a mold, the surplus lead being allowed to escape through a small hole. Five sizes of plugs were used, $\frac{7.5}{100}$, $\frac{6}{10}$, $\frac{5}{10}$, $\frac{4}{10}$ and $\frac{3}{10}$ in diameter. The first three sizes were about 1 inch long, the $\frac{4}{10}$ was .8 inch long, and the $\frac{3}{10}$ was .6 inch long. The table of the compression of these with the corresponding foot-pounds by the pendulum hammer is given on page 22 of the Report. We have constructed the curves represented in this table on Plate II. In the construction the same linear value is given to one foot-pound as to $\frac{1}{1000}$ of an inch of compression.

In regard to the curves for the smaller leads, $\frac{3}{10} \times .6$, $\frac{4}{10} \times .8$ and $\frac{5}{10} \times 1$, it will be noticed that the curves have a certain parallelism. The $\frac{3}{10}$ and $\frac{4}{10}$ curves nearly coincide, which shows that shortening the plug compensates, in a measure, for increasing the diameter. This appears from our general equation for cylindrical plugs,

$$x = \frac{KVy^a}{L - y};$$

for since $V = LA$, A being the area of top of plug,

$$x = \frac{KALy^a}{L - y},$$

which shows that the work is directly proportional to the original area of cross section, and, since L is greater than y , x is a decreasing function of L ; that is, the shorter plug requires more work for equal compressions.

But we also see from the same equation that for plugs of a given diameter or area A , since L enters both numerator and denominator, that *small variations* in the length will affect the work very slightly, which is some comfort to a man who cuts his plugs in a miter box.

Now, in regard to the curve for the $\frac{3}{10}$ lead, if we assume that it is represented by the equation

$$x = \frac{KVy}{L - y} \text{ or } x = \frac{By}{L - y},$$

in which the exponent of y has been omitted and L is equal to 601, and substitute the values of x and y given in General Abbot's table (omitting values of x less than unity), and compute the corresponding values of B , we have the following:

Foot-pounds.	Compression $\frac{1}{1000}$ inch.		
$x = 2.496$	$y = 90$	$B = 14.2$	
$x = 5.612$	$y = 160$	$B = 15.5$	
$x = 9.932$	$y = 232$	$B = 15.7$	Mean $B = 15.1$,
$x = 15.460$	$y = 300$	$B = 15.5$	
$x = 22.090$	$y = 357$	$B = 15.1$	
$x = 29.870$	$y = 404$	$B = 14.5$	

from which we see that B is very nearly constant, and the curve for the $\frac{3}{10}$ lead can be quite accurately represented by the equation

$$x = \frac{15y}{601 - y}.$$

If we treat the curve for the $\frac{4}{10}$ lead the same way and calculate the values of B for the same values of x (neglecting those below 10), we will find B to vary between 31.7 and 36.5; in other words, y in the equation of this curve needs a very small exponent. For the

$\frac{5}{10}$ and $\frac{6}{10}$ curves we find B to increase a little faster. For the $\frac{7.5}{100}$ lead, using the equation

$$x = \frac{By}{1006 - y},$$

we find the values of B to increase pretty steadily from

$$x = 9.9, \quad y = 75, \quad B = 123,$$

to

$$x = 165, \quad y = 500, \quad B = 166.$$

From this discussion we see that the value of α , the exponent of y , in the equation

$$x = \frac{By^\alpha}{L - y},$$

increases with the diameter of the plug; that it is about unity for the $\frac{3}{10}$ plug, probably less than unity for smaller sizes, and is about 1.1 for one-inch plugs.

Moreover, if we construct a logarithmic curve for each of these leads (as I have done, though they are omitted in the plates) from the equation $x = \log(1 - y)$, taking the length of the plug as unity, and assuming a modulus which will make the logarithmic curve coincide with the real curve for small values of y , we find that the fault of the logarithmic curve is that it is too nearly straight, that it lies between the real curve and the axis of Y , but that it agrees better with the real curve for the smaller leads than the larger. The inference is that there would only be coincidence for a lead indefinitely small, and, since the logarithmic curve is deduced under the hypothesis that the density of the plug remains constant during compression, we conclude that the density during compression increases the more rapidly as the diameter of the plug is greater.

If we now consider the curves (Plate II) for the $\frac{5}{10}$, $\frac{6}{10}$, and $\frac{7.5}{100}$ leads, which were all one inch in length, we see that they have not the parallelism of the $\frac{3}{10}$, $\frac{4}{10}$, and $\frac{5}{10}$ curves, but though they diverge, they are regular and consistent one with another, the plugs showing more work for the same compression in proportion to their size. To see how exactly this proportion holds, we will assume that for a given compression the work is proportional to the area presented to the hammer or piston.

If the density remained the same, this area would be proportional to the original area. Moreover, if in two plugs of different diameters but the same length the law of change in the density were the same—that is, the densities of the two were equal for equal compressions—the *works* would still be related as the original areas. If the leads are of equal hardness, this is implied in one general equation,

$$x = \frac{KA Ly^a}{L - y},$$

provided the value of a is independent of the diameter. Now, if we consider two plugs, such as the $\frac{6}{10}$ and $\frac{7.5}{100}$, the law of change in the density would not be exactly the same. If we reflect that the density increases because the flow of the metal is retarded, we see that the density must increase more rapidly in the larger plug, and this for a given compression should show more work than its relative area calls for, a conclusion we had already arrived at in another way.

To illustrate this I have attempted to reduce the curve for the $\frac{5}{10}$ lead to that for a hypothetical $\frac{6}{10}$ lead by multiplying its values of x (foot-pounds) by 1.44, the ratio between the original sectional areas; also the $\frac{6}{10}$ curve to a hypothetical $\frac{7.5}{100}$, by multiplying x by 1.56.

It will be seen that the agreement of the reduced curve in both cases with the original curve is very close for low compressions, but there is a difference for higher compressions, the real plug showing a little more work for the same compression. The divergence to the right of the curve for the real and larger plug is represented in one equation by a slight change in the exponent a , which, as we saw before, increases slightly with the diameter.

For the sake of comparison, I have plotted on Plate I the curve for General Abbot's $\frac{7.5}{100}$ lead, and deduced from it the curve for a hypothetical one-inch plug by multiplying the values of x by 1.78. This hypothetical one-inch plug differs from a real one-inch plug made from the Abbot lead in the same way that the hypothetical $\frac{7.5}{100}$ varied from the real plug of that size. If we had chosen to assume that the same law held, we could have drawn the curve for the real plug pretty accurately, but the hypothetical one answers our purpose. The conclusion is that the Abbot lead was softer than

mine, as it shows less work for the same compression. It was probably a very pure lead from one of the Galena ores, which is especially noted for purity. Mine was Selby lead, and contained a small percentage of hardening impurities, which did not affect, however, its fitness for the purpose. The superintendent of the Selby Smelting Works informed me that the impurities were small quantities of antimony and zinc. A San Francisco chemist of repute once told me that it carried also traces of silver.

Since the above was written I have tested some *pure* lead plugs, cut like the first from one-inch lead bar. Mr. Alfred Rupp, of the Selby Works, was kind enough to have the lead analyzed for me. He writes that it contains only *traces* of zinc and antimony.

I determined a short curve for these plugs by making a series of experiments with the foot-pounds machine. The curve, which is remarkably uniform, is plotted near the hypothetical curve for Abbot one-inch lead, and agrees with it very closely. It is also plotted in Plate II. By reasoning on the curves it is easy to see that this lead agrees very nearly in properties with the Abbot lead. It was probably a little softer than the Abbot.

We can sum up this part of the subject by saying that the relation between work and the compression of cylindrical lead plugs by a falling weight may be approximately represented by the general equation

$$x = \frac{KVy^a}{L - y},$$

in which K is a constant depending upon the nature of the lead, V the original volume, L the original length of the plug, and a a small exponent which increases slightly with the diameter.

It will be shown later that the *form* of this equation is incorrect, but the co-ordinates given by it are quite accurate, except near the origin.

THE ANOMALOUS SUB-AQUEOUS ACTION OF NITRO-GLYCERIN.

Returning to consider General Abbot's work, we note his table of the relative intensities of action of various high explosives, which has been quoted so often that it has become classical. It is here given for a few of the most prominent explosives only. I have

added the relative energies calculated from the intensities by General Abbot's rule.

Explosive.	Action under water.	
	Relative intensity.	Relative energy.
Dynamite,	100	100
Explosive Gelatine ('81),	117	126
“ “ ('84),	142	169
Forcite,	133	153
Dualin,	111	117
Hercules No. 1,	106	109
Gun-cotton,	87	81
Mica Powder No. 1,	83	76
Nitro-glycerin,	81	73
Mica Powder No. 2,	62	49

It must be noted that these relative intensities are taken horizontally. General Abbot also gives (p. 110) the relative intensities taken vertically upward and downward, dynamite being again taken as the standard. Lieut.-Col. J. P. Farley, of the Ordnance Department, in a recent paper, "Compilation of Facts Relating to High Explosives," published in the Journal of the Military Service Institute, November, 1891, falls into a serious error in commenting upon General Abbot's work in the following sentence: "It has been shown experimentally that the forces developed by a subaqueous explosion indicate that the normal line of maximum intensity will be directed downward," whereas the maximum effect is upward. Colonel Farley was probably misled by the table on page 110, in which dynamite is taken as 100 in all three directions, the numbers in each column being relative only to themselves, but it is shown by the context and pictorially by Plate XIV that its action is fifty per cent. greater upwards than downwards. This error, which is probably nothing more than the slip of a pen on the part of Colonel Farley, is mischievous, because it tends to confirm a foolish notion firmly rooted in the minds of miners and other practical men that high explosives have some special property of acting downwards. This table is very instructive, as it shows a greater relative efficiency downward for the more intense acting explosives. To illustrate, dualin, which gives 111 compared with dynamite horizontally, gives 116 compared with it downward (really 68 compared with its own upward action, and 80 with its own horizontal action

taken as 100). Hercules gives 106 horizontally and 109 downwards. Explosive gelatine (1881) 117 horizontally and 125 downwards. (The downward action of dynamite is 64 compared with its upward action, and 77 compared with its horizontal action.) General Abbot appropriately remarks: "The greater the resistance to be overcome the more distinctly marked are the differences between the intensity of action of the several explosive agents. In other words, the most severe test of their relative power under water is their action vertically downward. As the work required of them in submarine mining, however, varies from the horizontal plane upward, their relative horizontal action appears to be the true criterion."

It is a remarkable fact that nitro-glycerin should stand so low in this scale—81 compared with 100 for dynamite. Its action downward shows a still more startling difference—71 against 100 for dynamite.

This anomaly is certainly very surprising, as it is generally acknowledged that nitro-glycerin in rock blasting does at least $\frac{4}{3}$ as much work under similar conditions of confinement as dynamite, or, in other words, gives the result naturally expected of it. Dynamite consists of 75 per cent. nitro-glycerin and 25 per cent. of an inert absorbent, kieselg  hr, which cannot be expected to add to the strength of the explosive, and yet, according to General Abbot, in sub-aqueous explosion the intensity of action of nitro-glycerin is only about $\frac{8}{10}$ that of dynamite or $\frac{6}{10}$ of what we would naturally expect.* "A part seems to be greater than the whole," to adopt an expression which the late impetuous Geo. M. Mowbray was wont to use in confounding the rivals of his tri-nitro-glycerin, and yet no one who reads General Abbot's Report can doubt for a moment that his rating of nitro-glycerin is a "fact." We may differ in interpreting his results, but the results must be accepted.

This anomaly receives an incidental discussion in a paper entitled "Explosives and Ordnance Material," by Mr. S. A. Emmens, published in the Proceedings of the U. S. Naval Institute, No. 59, 1891. The paper is very entertaining, and furnishes much food for thought. Mr. Emmens gives General Abbot's theory as summarized by Pro-

*This is only rough reasoning. The real discrepancy is larger. General Abbot uses mean intensity of action as a measure. If he had used work—quantity of action—the figure for nitro-glycerin would have been about 73, not quite 55 per cent. of normal—133.

fessor Munroe, which (p. 110, "Submarine Mines,") is thus given by General Abbot himself: "Dynamite No. 1 is simply nitro-glycerin granulated. With gunpowder granulation promotes intensity of action by opening passages for the initial flame to permeate the mass and thus accelerate the formation of the gases. Were this the true explanation of the phenomenon in question, a similar relative strength between the two explosives would also be shown in rock blasting, which is contrary to observation, as nitro-glycerin in hard rock is admitted to be by far the stronger of the two. Let us suppose, on the other hand, that granulating nitro-glycerin by absorbing it in kieselgüher has precisely the contrary effect, *i. e.* that the particles of silica slightly retard chemical action, as is not unlikely, since in detonation the reactions may occur within the molecules. This idea appears to me to supply the required explanation; for the resistance opposed by water, being of a slightly yielding character, may exact more time than is afforded by nitro-glycerin pure and simple. I regard this as the most plausible explanation of a fact which, although novel, is so well established by my experiments that its correctness can hardly be questioned."

Mr. Emmens takes issue with General Abbot, and objects to the nitro-glycerin in dynamite being considered granulated, because "careful inspection shows no interruption of liquid continuity in the nitro-glycerin constituent of dynamite." One might interpret this sentence to mean that the dynamite consists of a continuous liquid with the solid suspended in it. The dynamite would then be almost incompressible and as sensitive as the liquid itself, but no such meaning was intended. I examined with a powerful microscope two varieties of dynamite—one, Nobel's, made in Scotland; the other made by myself from German kieselgüher. Under the microscope, although there is a marked granulation, the liquid appears to predominate much more than to the naked eye. The appearance by transmitted light is something like a pile of dirty snowballs. In the sense that every particle of the liquid at certain points touches other particles, or, in other words, that there is no particle completely isolated from its fellows, I think Mr. Emmens is right.

He then makes this point: "Moreover, the reference made by Professor Munroe to certain dynamites 'which are made so as to explode with exceeding rapidity, and which fall very low in the scale,' is not borne out by the best-known of such quick-action

dynamites, viz., Mowbray's mica powder. No. 1 grade of this powder, containing only 52 per cent. of nitro-glycerin, gave a force of 102, as compared with 100 for pure nitro-glycerin."

Of course Professor Munroe's comparison, based on General Abbot's views, was with dynamite. Nitro-glycerin itself is low in the scale.

Still Mr. Emmens' point is well taken. If quickness were a cause of failure, why should quick mica powder give 83 compared with 100 for dynamite, when it contained only $\frac{70}{100}$ as much explosive matter? A part of this discrepancy disappears if we compare the energies instead of intensities—100:76 instead of 100:83. Another answer to the riddle is that there is no *proof* that mica powder was specially quick, except the dictum of Mowbray, which General Abbot gives without endorsement, but to which he attaches too much importance. It must be remembered that Mowbray was sued for infringement of the dynamite patent by the Atlantic Giant Powder Company, and he was cudgelling his brain for some point upon which to hang a specific difference. Mica powder, in the opinion of fair-minded, practical men, was a bold infringement of Nobel's invention; but Mowbray made a gallant fight, which consisted of unflinching assertions based upon *à priori* reasoning.

Mr. Emmens solves the problem by his "Ballistic Theory of Explosives," which is based upon the kinetic theory of gases, according to which the pressure of a gas upon the walls of its containing vessel is caused by impacts of the gaseous molecules upon the walls. The *vis viva*, or energy, of the molecules has two factors—mass and velocity. "The character of the blow as regards the effect produced upon the body struck must be different in the cases of two projectiles, one of which (say a molecule of carbonic anhydride) weighs 22 times as much as the other (say a molecule of hydrogen), even though the energies of the two blows be equal." He then illustrates his theory by a proximate calculation of the factors mass and velocity in the case of nitro-glycerin and dynamite. We have no exception to take in the case of nitro-glycerin. He first calculates the volume of gases produced by 1000 grammes of nitro-glycerin (reduced to 0° C. and 760 m.m. of mercury), then the temperature of the gases, then the volume due to this temperature, and finds this quantity 18,738.7 liters. He then proceeds as follows: "But if the nitro-glycerin be confined in a shell, for

example, then 18,738.7 liters would be compressed within the space of $\frac{1}{1.6}$ liters, and therefore would press upon the walls of the shell with a force equal to $18,738.7 \times \frac{1.6}{1} = 29,981.9$ atmospheres. The mass being 1000 grammes, the velocity factor may be taken as $\frac{29,981.9}{1000} = 29.9819$." I think no one can take exception to this reasoning, but when it comes to dynamite the case is different. Having calculated the elements as before, he finds the expanded volume of the gases 10,861 liters and "the silica expanded 20.05 cubic centimeters in excess of its original volume. But if the explosion took place in a close vessel, the space available for the gases would be $\frac{1}{1.6} \times \frac{3}{4} - 20.05 = .4487$ liters, and the pressure would therefore be $\frac{10,861}{.4487} = 24,205.5$ atmospheres. The mass factor of this pressure is 750 (as the dynamite gases have but .75 of the weight of the gases produced by 1000 grammes of nitro-glycerin) and the velocity factor is $\frac{24,205.5}{750} = 32.27$." I hold that this calculation is open to such serious criticism as to impair the conclusion in its general application to dynamite. It is plain to see that this result is a question of density of loading.

For nitro-glycerin this is properly assumed as 1.6, and the 1000 grammes of products occupy $\frac{1}{1.6} \times 1000 = .625$ liters, while for dynamite, as the space available for the gases is only .4487 liters—if we take into account the loss of space by expansion of the silica—the original space allowed was .46875 liters, corresponding to a density of 2.13 for the dynamite. The density of the dynamite compacted into cartridges is 1.4. It appears, therefore, that Mr. Emmens' calculation applies only to a theoretical case which cannot be realized in its essential conditions.

As to the effect of density of loading in General Abbot's experiments, the latter show that within wide limits his results are independent of it. If it be contended that Mr. Emmens' reasoning is strictly theoretical and based upon ideal conditions, the answer is that it is offered as the explanation of a practical problem—the anomalous action of nitro-glycerin and dynamite in sub-aqueous explosion. General Abbot has shown that a void, as he calls it in his table, of three times the volume of the charge does not affect the registered energies of dynamite.

If Mr. Emmens is right, the presence of the inert matter in dynamite gives additional velocity to the molecules of the gases, whereas one would naturally think that it would impede their motion slightly.

This latter idea is borne out by tests with the crusher gauge, made by Drinker himself. (See "Tunneling, Explosive Compounds and Rock Drills," pages 78 and 79.)

"The second trial was to test whether in ordinary No. 1 dynamite (or giant powder), composed of 75 per cent. of nitro-glycerin and 25 per cent. infusorial earth, there was any appreciable loss of power by the absorption of the nitro-glycerin in the infusorial earth.

"(a) Charge 1.5 grammes No. 1 dynamite.

Mean height of leads before firing,	.932"
" " " after "	.194"
compression	<u>.738"</u>

"Next the amount of pure nitro-glycerin combined in 1.5 grammes No. 1 dynamite was taken.

"(b) Charge 75 per cent. of 1.5 grammes=1.125 grammes nitro-glycerin.

Mean height of leads before firing,	.933"
" " " after "	.180"
compression	<u>.753"</u>

"Therefore

"(c) Compression exerted by No. 1 dynamite,	.738"
" " " nitro-glycerin alone,	.753"
In favor of nitro-glycerin alone,	<u>.015"</u>

"This difference is very small; still it would appear sufficient to indicate, if not a *practical*, still a positive and *appreciable* diminution of the effective power of the nitro-glycerin by the absorbent." This small difference, .015", is the less insignificant on account of the conical shape of Drinker's plugs. The comparison, it must be noted, is between a certain weight of dynamite and three-fourths of the same weight of nitro-glycerin.

I have repeated Drinker's experiment several times, and have also varied it slightly by taking the weight of the nitro-glycerin as a fixed quantity. I first fired 24 grains of nitro-glycerin and noted the compression. To a second charge of 24 grains, weighed and placed in the cavity of piston, I added 8 grains of kieselg hr,

which I mixed carefully with the point of a knife. In every case I have confirmed Drinker's conclusions.*

To resume, Mr. Emmens finds that the ratio $\frac{29.98}{32.27}$ between the velocity factors which he has calculated for nitro-glycerin and dynamite, agrees fairly well with the intensity ratio observed in the course of General Abbot's experiments, certain allowances being made. We have shown, we think, that no credence is to be given to the figure 32.27 as applied to dynamite.

He goes on to compare the figures with those of Lieutenant Walke's recent experiments, but in this he falls into a grave error. Lieutenant Walke expressly explains that his compressions are not to be assumed as direct measures of either energy or intensity, and in arranging his table he is careful to use the expression "*order of strength.*" Nevertheless Mr. Emmens treats the figures representing the order of strengths (which are directly proportional to the compressions, taking the compression for nitro-glycerin as 100) as energy measures, so that his reasoning on them is vitiated. There is a hopeless confusion in all this of energy or quantity of action with intensity of action.

But if Mr. Emmens' theory is wrong, how is the anomaly, which he aptly calls the "Abbot effect," to be explained?

If we admit that the shock of nitro-glycerin is greater than the shock of dynamite, which is a fair general assumption, and yet we find that the effect of the shock transmitted through water is the greater for dynamite, one of two things must be true: either there was

* In the same series of experiments I tried the effect of a variety of substances by adding 8 grains of each to the regular charge of nitro-glycerin—an interesting investigation, the results of which were briefly as follows: Nearly all the substances tried showed an *increase* of compression, except inert mineral *absorbents*. The better the absorbent the greater the falling off in the compression. Clean, sharp sand is neutral, or nearly so. Overburnt charcoal shows a slight increase; underburnt charcoal has greater effect; bituminous coal still greater. Water shows a very great increase, due partly to tamping action, as it floats on the top of the nitro-glycerin; but even when divided up by using 4 grains of wood pulp and 4 grains water, it still shows a considerable effect, nearly equal to the wood pulp alone. The substances giving the greatest effect are wood pulp, fine sawdust or other vegetable fibre, pulverized sugars, starches, bituminous coals, anhydrous oxalic acid, paraffin wax, petroleum oils, etc.

The conclusion I arrived at was that the increase in some cases was partly due to the oxidizing effect of the surplus oxygen in the nitro-glycerin (as in the case of the charcoal), but generally and chiefly to the production of additional amounts of gas.

In the case of the sand, the union is not close enough to have any effect.

In the case of inert absorbents like kieselgühr, the heat and motion are shared with the solid particles without compensation.

In the case of organic absorbents and other active substances, the heat and motion are shared, but this is more than compensated for by the production of additional gas. The subject, however, is too large to be fully discussed in a foot-note.

something in the conditions to vitiate our premises in regard to the relative intensities of the initial shocks, or the whole shock has not been *transmitted* in the case of nitro-glycerin, part of the energy being lost in the medium. The second horn of the dilemma is the one which General Abbot accepts, in saying that the "resistance of water, being slightly yielding, may exact more time than is afforded by nitro-glycerin." But we will consider the other first. The only condition which could vitiate our premises is a loss of part of the nitro-glycerin, that is, the whole charge is not exploded.

This view is more worthy of consideration than appears at first blush. Perhaps the liquid condition of the explosive (for nitro-glycerin is singular in being the greatest anomaly in the table as well as the only liquid), in presenting an almost incompressible medium for the transmission of pressure to the containing case, may offer an explanation. Is it possible that the initial shock, set up by the detonator, could burst the case (usually an open tin can or glass bottle) before the whole body of the liquid charge exploded? This gives rise to a number of interesting questions. Is there an *explosive* wave independent of the *pressure* wave? If so, has one greater velocity than the other? If we can rely upon certain English experiments, both questions may be answered, I think, in the affirmative. In this connection we cite the attempts of Captain Nobel, in England, to measure the velocity of detonation of dynamite, gun-cotton and nitro-glycerin. I have no record at hand except a scant memorandum, but if my recollection does not play me false he found the velocity for dry gun-cotton to be about 17,000 to 18,000 feet a second, the velocity for dynamite about the same, and the velocity for wet gun-cotton 18,000 to 21,000 feet a second. These explosives were fired in long paper cylinders. For liquid nitro-glycerin in V-shaped wooden troughs he found the velocity about 5000 feet a second.

The velocity of the pressure wave is simply the velocity of sound. Liquid nitro-glycerin would transmit sound much more rapidly than a heterogeneous, inelastic mixture like dynamite. We may then say that nitro-glycerin transmits pressure to the case very rapidly, while the detonation proceeds slowly, and dynamite transmits pressure very slowly while the detonation proceeds rapidly.

Contrary to general belief, the explosion of nitro-glycerin or even dynamite, though rapid, is by no means instantaneous. If a cart-

ridge of dynamite is placed on end on an iron plate and fired with a detonator at the top end, the effect is greater than if the detonator be placed at the lower end. If the detonation were instantaneous, the effects would be the same. Being progressive, the action is easily explained. This being granted—that time is a necessary element in detonation—there are facts which seem to show that special conditions are required to insure the *complete* explosion of nitro-glycerin and its compounds.

Mowbray noticed at the Hoosac Tunnel that weak detonators did not fully explode his charges of nitro-glycerin—a part was blown out in vapor. In mining with dynamite the atmosphere of the drift often becomes laden with the vapor of nitro-glycerin, giving tyros and even experienced miners the characteristic headache. (See article by Dr. Darlington, of Arizona, in the Scientific American Supplement No. 786, January 24, 1891, republished from the Medical Record.) This effect is a general complaint against nitro-glycerin preparations, and is *not usually attributable to weak detonators* but to improper loading. In rock blasting it can be prevented, in my opinion, by careful loading, proper placing of the detonator, and good tamping.

Returning to consider our charge of nitro-glycerin in the tin can or glass bottle, if we admit the possibility of some portions of the liquid escaping from the case before they are exploded, the conditions are right to preserve these particles from subsequent explosion. Being finally divided by the blow which scatters them, they would form instantly an emulsion with the surrounding water, and thus be protected. In support of the protection afforded by this condition, I can cite some facts from my own experience. It has been my fortune to inspect, immediately after the accident, the ruins of several nitro-glycerin explosions, where tons of the liquid went off, creating havoc with buildings, lead vats, and, unfortunately, sometimes with human bodies. One would naturally suppose that not a particle of nitro-glycerin within a radius of fifty feet would escape explosion. Buckets of the liquid one hundred and fifty feet away have been known to explode by “sympathy,” blowing the Chinaman who was carrying them to pieces. Yet, when the ruins are overhauled, men handling the timber and litter get violent headaches, showing the presence of the liquid—in fact, it has been found in considerable quantity among the débris. The explanation is that this liquid

was at the time of the explosion an emulsion with either water or acid.*

The only strong argument against my suggested theory of a loss of nitro-glycerin is that the acute experimenters handling and firing many charges should have given it no countenance. However, General Abbot's experiments were made a good many years ago, when simpler views prevailed in regard to detonation, and nitro-glycerin was believed to be the quickest of explosives.

We will now consider his own explanation—a loss of energy in the medium transmitting the shock. If we admit that the liquid is all exploded and that its shock or initial energy is greater than that of dynamite, and yet when we measure the energies transmitted to the plugs through a foot or more of water, we find the dynamite registering more than the nitro-glycerin, the conclusion is inevitable that the intervening water has absorbed some of the energy, and the relative quantity absorbed is greater in the case of the nitro-glycerin than in the case of the dynamite; in other words, the water has been heated more by the nitro-glycerin.

If the water were incompressible it would transmit the energy in both cases without diminution (except by the law of the square of the distance). Being compressible, if it were perfectly elastic, it would still transmit the energy undiminished in the ideal case, the heat of compression being balanced by the cold of expansion. Water for the purposes of this discussion *may be regarded as perfectly elastic*, and any *confined* portion of it will transmit energy undiminished. The law of its heating by compression was experimentally determined by Joule. If the heat is not allowed to leave it, it regains its original volume and temperature when the pressure is removed. In General Abbot's experiments the water was not confined, and part of the heat of compression may have been dissipated beyond the orbit of his registering plugs. We may suppose the relative loss was greater in the case of nitro-glycerin than dynamite. On this slender thread it seems to me his theory hangs.

*A charge of about 1700 pounds of nitro-glycerin, agitated in a lead "nitrator" or "mixer" with about four times its weight of acid, has been known to withstand the shock of nearly a ton of the liquid exploding within four feet of it. The mixer, with its lead coils still in it, torn from its foundations, thrown perhaps twenty feet and crushed into a shapeless mass, showed no signs of an explosion inside.

An equally perfect agitation with half as much water (as acid) would probably have the same protecting effect, the protecting effect being a question of specific heat.

Although I have held these theoretical views for a long time, it is only lately that I have attempted to test them by a practical experiment. My object was to prove whether or not there was anything in the nature of water which rendered it a better medium for transmitting the shock of dynamite than for transmitting the shock of nitro-glycerin. To the instrument designed for this purpose I have given the name "water crusher gauge."

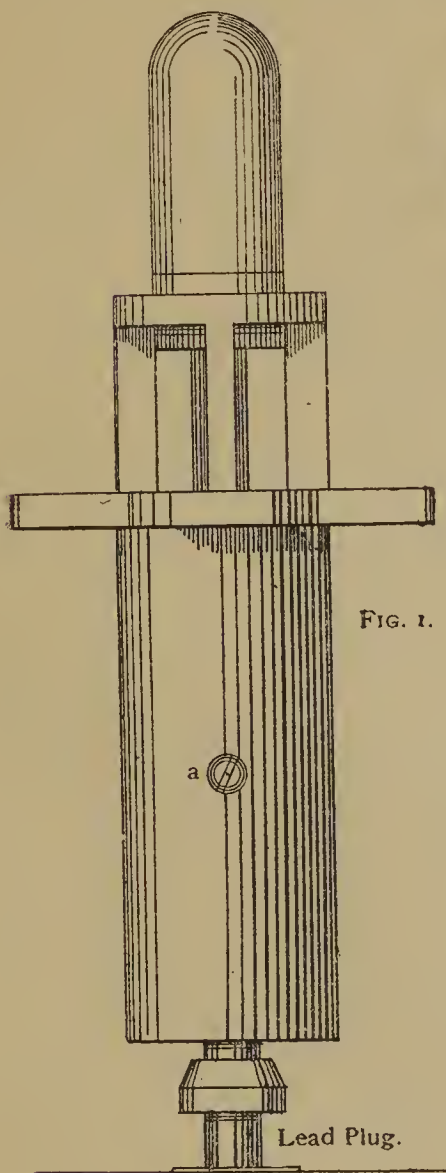


FIG. 1.

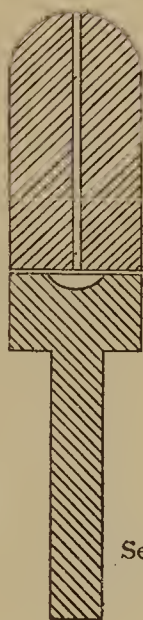
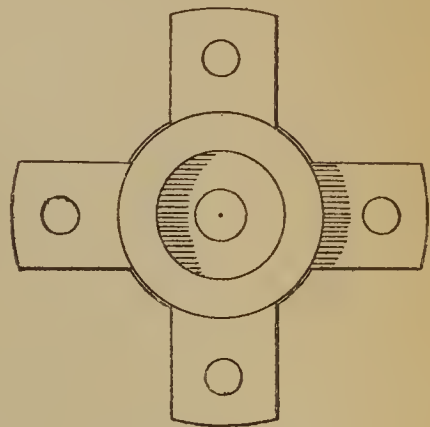
FIG. 2.
Section of Pistons
and Shot.FIG. 4.—Top View.
Shot and Piston
removed.

FIG. 3.

WATER CRUSHER GAUGE.

This instrument consists of a brass cylinder 4 inches in outside diameter, with a bore-hole exactly one inch in diameter. The extreme length is $14\frac{1}{2}$ inches; $3\frac{3}{4}$ inches below the top are projecting lugs to rest on the ring of the Quinan gauge, to which they are firmly bolted. This brings the cylinder inside of the slides, the lower end being about $2\frac{1}{2}$ inches above the steel block, upon which the lead plugs are crushed. Above the lugs the brass cylinder be-

comes a skeleton support and guide for the piston, and consists of a ring and four upright guides.

The pistons are of steel. The top piston has a total length of $6\frac{1}{2}$ inches. The lower part, 1 inch in diameter and 5 inches long, is fitted to the bore of the cylinder. The upper part, $2\frac{1}{2}$ inches in diameter, is fitted to slide between the guides and through the brass ring. The powder cavity is small, 1 inch in diameter and $\frac{3}{8}$ inch deep. The lower piston is shorter, the portion fitted to the bore of the cylinder being $2\frac{1}{2}$ inches long.

The shot is 5 inches long and $2\frac{1}{2}$ inches in diameter.

The instrument is designed to transmit the blow through a column of water enclosed between the two pistons. The length of the column of water used was 6 inches.

The apparatus was so well made that the pistons were air-tight. When one was pushed in, the other was pushed out by the air.

In operating it, the lower piston was carefully oiled and inserted in place, and the cylinder bolted to the ring of the large crusher gauge. The lead plug was placed under the lower piston, and the bore-hole filled with water, the gauge being brought to the perpendicular for the purpose. The top piston, carefully oiled, was then entered. The small screw *a* on the side of the cylinder which communicates by a $\frac{1}{8}$ inch hole with the bore, was then loosened, and enough water drawn off to allow the top piston to descend until exactly 6 inches of the column of water remained in the cylinder. The screw was then driven in tight with a screw-driver. The charge of explosive was placed in the cavity, the shot, with capped fuse already inserted in it, was placed on top, and the charge fired.

Castor oil was used to lubricate the pistons. During the experiments it was found advisable to support the top piston at the exact point by placing upright under it a piece of pine wood about the size of a parlor match, as the screw leaked slightly, unless driven home very hard, and allowed the piston to descend too far, especially when the weight was increased by putting on the shot.

The only defect developed during the trials was that the steel had not been tempered sufficiently hard. The cavity in the top piston became roughened by the gases and the fuse-hole in the shot considerably enlarged, which caused a falling off in the apparent strength of the different explosives; but as these were made to alternate in the firings, and a comparison only was aimed at, the defect was not serious.

The weights of the moving parts were as follows :

Weight of shot,	90	ounces.	
“ “ top piston	50	“	} 73.73 ounces.
“ “ lower “	21	“	
“ “ water	2.73	“	
“ “ middle piston,	5	ounces	(to be described later).

The compressions were reduced to foot-pounds by the curve for soft lead plugs on Plate II, which curve was determined specially for these plugs.

The uniform charge selected was 10 grains, a small charge, but the delicate nature of the apparatus seemed to prohibit a very heavy shock. It will be seen that during the experiments it received such a shock and stood it very well.

The detonator used was a triple force cap, supposed to contain, beside fulminate, a small per cent. of gun-cotton. The caps were not as uniform as could be wished. In the preliminary experiments, made to determine their strength, the compression ranged from 104 to 132. The mean work of the cap was taken at 30 foot-pounds.

The experiments were as follows, it being understood that the tests were not in the order given, the results for each explosive being segregated:

Nitro-glycerin.—Anhydrous, several months old, charge 10 grains.

	Compression in $\frac{1}{1000}$ inch.	Foot-pounds.	Foot-pounds corrected for cap.	
	379	183	153	
	381	184	154	
Shot No. 6	<u>669</u>	<u>600</u>	<u>570</u>	anomalous, rejected.
	377	180	150	
	369	173	143	
		Mean work,	150	

Dynamite.—The dynamite was made from the same nitro-glycerin and German kieselguhr, 75 per cent. of the former and 25 per cent. of the latter, charge 10 grains.

Compression.	Foot-pounds.	Foot-pounds corrected.
336	147	117
323	137	107
308	127	97
310	129	99
	Mean work,	105

Ratio of mean work of dynamite to mean work of nitro-glycerine, $\frac{105}{150} = 70$ per cent.

Gun-cotton.—This was a very strong explosive, made by nitrating a fine hydrocellulose, which was obtained from cotton-waste. The gun-cotton was in fine powder, charge 10 grains.

Compression.	Foot-pounds.	Foot-pounds corrected.
312	130	100
310	129	99
		<hr/>
	Mean work,	99.5

Ratio of work of gun-cotton to work of nitro-glycerin $\frac{99.5}{150} = 66.3$ per cent.

This is probably low, as the gun-cotton was tried after the gauge had suffered some deterioration.

The ratio 70 per cent. for dynamite and nitro-glycerin, though a little low, is the ordinary crusher gauge effect, which, as proved by many experiments (including those of Drinker, already referred to) shows a strength for dynamite a little less than that due to the contained nitro-glycerin.

To test this anew, the water gauge was converted into an ordinary gauge by dispensing with the water column, and inserting between the two pistons the piece of steel shown in Fig. 3. This was made as light as possible, so as to approximate the weight of water for which it was substituted. It weighed really 5 ounces instead of 2.73, making the relative weights of the shot and compound piston 90 : 76 instead of 90 : 74, as in the water gauge.

This change had a slight effect in lessening the compression probably, but the compression was still more reduced by the lack of continuity in the compound piston. In these experiments, the middle piston being only $3\frac{3}{4}$ inches long, I used a steel plate $\frac{1}{2}$ inch thick under the lead plug, and the joint between the top piston and the shot in the firing position came *below* the brass ring of the cylinder.

The caps were tried again, and their mean work averaged at 32 foot-pounds.

Nitro-glycerin.—Same as before, charge 10 grains, all steel compound piston.

Compression.	Foot-pounds.	Foot-pounds corrected.
346	156	124
321	136	104
Mean work,		114

Dynamite.—Same as before, charge 10 grains, all steel compound piston.

Compression.	Foot-pounds.	Foot-pounds corrected.
298	120	88
280	108	76
Mean work,		82

Ratio of work of dynamite to work of nitro-glycerin $= \frac{82}{114} = 71.9$ per cent. This agrees well with experiments in the large gauge.

Gun-cotton.—Same as before, only one shot was fired with gun-cotton, charge 10 grains, all steel compound piston.

Compression.	Foot-pounds.	Foot-pounds corrected.
305	124	92

Ratio of work of gun-cotton to work of nitro-glycerin $= \frac{92}{114.5} = 80$ per cent.

This is too large, but agrees fairly well with tests of this gun-cotton in the large crusher gauge.

The following observations were made with the water gauge: Sometimes both pistons rebounded slightly, and the lower piston was found a half inch or so above the lead. Usually the lower piston was found in contact with the lead. No loss of water could be detected by measuring the column of water, including the lengths of the pistons immediately after firing. No increase in the temperature of the water could be detected.

Shot No. 6 with nitro-glycerin is to be explained in this way. The proper firing position for the top piston is shown in the sketch. The joint between the piston and shot should be about $\frac{3}{8}$ inch *above* the brass ring of the cylinder. In this shot the screw was not driven in tight, and when the shot was put in place the piston slowly sank during the burning of the fuse till the joint came well down in the ring. When the charge was fired the gauge was converted for the moment into a mortar, the gases being confined by the tight-fitting ring. The weight of the compound piston was also lessened by the

loss of water, but the influence of this was slight compared to the mortar effect of the ring. The result of the shot was the tremendous compression of the plug as shown, but this gives only a faint idea of the exhibition of power. The shot was thrown probably 40 feet into the air, *and was followed an instant or two later* by the top piston, which was thrown still higher, and fell at least a half second after the shot. Part of the water was also thrown out in a jet. The actual compression of the water must have been considerable to produce such effects. Unfortunately it was not measured.

In discussing the experiments with the water-crusher gauge, we think we are justified in saying that *there is nothing in the nature of water which makes it a better medium for transmitting the energy of dynamite than for transmitting the energy of nitro-glycerin*. It is not claimed that the conditions of explosion were the same as in General Abbot's experiments. I employed a *confined column* of water, acted upon by a steel piston of considerable weight. Under these conditions water seems to transmit the whole force of nitro-glycerin. It is undoubtedly compressed and heated, but the subsequent expansion and cooling restores the energy without sensible loss. If the experiment could have been conducted with a piston without weight, the expansion of the water might not have made this compensation, although there is no reason to believe that this would have been to the advantage of dynamite. In this case, if the explosive were quick enough to complete its work and then condense before the phase of water expansion set in, the expansion would be without effect on the plug. In my experiments the inertia of the piston served to make the expansion of the water contribute its quota to the crushing of the plug. In one experiment only, No. 6, did the inertia of the piston appear to be inadequate. In this instance a portion of the energy imparted to the water was not transmitted to the plug, but was expended by the rebound in projectile force.

Too much importance, however, must not be attached to this difference between my conditions and those of General Abbot. It is true, the blow of his charge was partly transmitted by water without the intervention of a block of steel having considerable weight (his piston being insignificant in this regard), but it must be remembered that his charges were incomparably larger, that they consumed a much larger interval of time in evolving their gases, and that the water acting upon the piston had in rear of it the sustaining

pressure of these gases, which must have acted somewhat like the inertia of my piston in directing the expansive force of the water, and, lastly, it must be noted that, at least in his larger charges, *his piston must have been acted upon directly by the gases themselves* for at least a portion of the period of explosion. The globe of gas must have extended far beyond the orbit of the plugs in some, if not all, of his charges.

The more the subject is considered the more strange the anomalous action of nitro-glycerin becomes, unless we adopt some very simple explanation, such as the loss of a portion of the charge in the surrounding water.

If this theory is correct the loss results from the incompressible nature of the liquid. There being no chance for expansion, the case is burst before the whole of the liquid is converted into gas, whereas with dynamite the interstitial spaces give a little time for this conversion before the pressure bursts the case. This theory could be easily tested. Divide the charge of nitro-glycerin among a number of very small, thin, glass bottles, the bottles being tared to get the weight of liquid. Fill each bottle not more than half full. Pack the bottles loosely into a strong case, using one as a primer. This experiment has the advantage of being perfectly feasible. If it gives a largely increased intensity of action for nitro-glycerin, we may regard the theory as proved. If it does not, then we have thrown no light upon the subject, and must "guess again."

LEAD AS A REGISTER OF WORK.

Lead has a good deal to recommend it as a material to register work. In the first place, it is very sensitive; secondly, a plug already partly compressed will register a second blow very accurately, the work corresponding to the second blow being equal to the work corresponding to the total compression, less that belonging to the first compression; or, if the plug retains the cylindrical form after the first compression, we can treat it as a new plug of larger diameter and shorter length with a curve of its own.

General Abbot notices this valuable property of lead, and makes use of it in his experiments (see page 138 of his Report).

I have made some special experiments to test the accuracy of the principle in the foot-pounds machine, and found it quite reliable through a wide range of compressions.

The question whether the work indicated by a given compression in the foot-pounds machine is exactly equal to the work corresponding to the same compression by an explosive in the crusher gauge has been mooted before. That it is approximately the same I have no doubt, but there are good reasons for believing that the agreement is not generally exact. If the two compressed plugs show the same form, we are entitled to think that the same resistance was developed, and in the same way. In my experience there is less difference in form when the lead is hard, and I therefore regard this material as the best. Soft plugs are more regular in form when compressed by a falling weight than by an explosive. When compressed by a weight they are cylindrical for small compressions and barrel-shaped for great compressions, the top and bottom remaining equal, or nearly so, in area. When the plug is compressed by a high explosive, the higher compressions are tub-shaped.

This difference of form implies a difference in the law of the resistance, and probably a difference in the amount of work. The most plausible explanation of this difference of form that occurs to me is a difference in the law of action.

In the case of the falling weight the first part of the compression is done rapidly; the action is a maximum at the beginning and decreases by a regular law. In the case of the high explosive the action begins as zero and rises to a maximum, and then falls to zero again. If the maximum is very near the close of the action, there may not be time for the flow of the metal to be equalized. The heat developed by the blow *softens the top part of the plug, which consequently spreads faster than the bottom.*

The same effect takes place with the falling weight at or near the beginning, but the effect is masked by the subsequent compression. Whether or not the *total time* of action is greater or less in the case of the explosive or the falling weight is a nice question.

General Abbot concluded, in his experiments, that the action of the pendulum hammer was much shorter in period than his high explosives. This might well be, as his charges were incomparably larger than crusher gauge charges and acted through a foot or more of water, whereas in the crusher gauge, from the arrangement of parts and the smallness of the charge, the time required to detonate the charge and complete its action on the plug must be very short; nevertheless, we believe the hammer or weight was quicker in its action in

performing the same work, for the simple reason that it begins its action as a maximum, whereas every explosive must begin as zero and develop its maximum action during the course of the work. We regard the *hammer action as a limit which explosives may approximate but can never reach*. This is not a rigorous demonstration, however, and I only offer it for what it is worth. We will touch upon this subject again.

A question allied to the one we have been discussing, viz., the equality between work by a falling weight and work by an explosive, is this: Is the compression by a falling weight the same for a given number of foot-pounds whether the latter be made up of many feet and few pounds or few feet and many pounds?

This it was easy to decide in the affirmative for at least *the range of the apparatus* by a few experiments in the foot-pounds machine.

COPPER AS A REGISTER.

There is another metal used to register the effects of forces in crusher gauges—copper. The parent form of the instrument was Rodman's indenting piston and copper disc. When Rodman first proposed this for measuring the powder pressure in guns, the theory of its operation was criticised by Professor Bartlett, of West Point. The practical usefulness of the Rodman gauge has been proved by many years' experience. Any error in the theory of its application affects equally the crusher form of the apparatus. The quantity aimed at in gun experiments is the maximum pressure or the maximum intensity of action, supposed to be represented by the final resistance to either the cutter or the crusher piston. The scale of pressures (that is, the reading for the cuts or compressions) is determined in our service, and I think also in Europe, by a testing machine sometimes called erroneously a dynamometer, a simple arrangement for weighing the pressure which is applied by a screw to the copper cylinder or discs. The staging supporting the copper is connected with a system of levers, one of which has a sliding weight to counterbalance and measure the pressure. It is assumed to be a fact with copper of a given quality that if the screw be driven *slowly*, the length of the cut of the indenting tool or compression of the cylinder is practically the same for the same pressure. When a certain cut or a certain compression has been made, the disc or cylinder can be replaced in the apparatus, and the same pressure applied without increasing either cut or

compression, provided it is applied slowly. General Abbot quotes the experience of English artillerists who found that a copper cylinder, compressed by a charge of gunpowder in a 12.5-inch gun, retained its reduced length unaltered, when the trial was repeated several times. The powder was a slow-burning, large-grain, 1.5-inch cubical. With lead, however, the case is quite different. Small pressures maintained for considerable periods produce the same results as larger pressures for shorter periods. For this reason General Abbot found it impossible to prepare a reliable scale for his plugs with the Rodman testing machine.

This difference of the two metals, notwithstanding that the practice of artillery experts may be properly based upon it, must be one of degree, due to the great difference in hardness, so that the above statements in regard to copper are to be received cautiously. In view of the fact that the resistance offered by lead is so susceptible to the influence of time, we may assume that copper resistance is not altogether independent of it. The use of the scale so determined to measure the effects of powder charges in guns has been criticised upon the general grounds that the action of explosives is analogous to a blow, and that ordnance experts confuse static and dynamic effects in treating this action as a pressure. Without giving any opinion at present upon the validity of this criticism, we may say one thing seems evident—the cut made by the indenting tool or compression by the piston, whether done in the testing machine or in a gun, is a register of *work*.

DYNAMIC TREATMENT OF COPPER.

I have, therefore, thought it well to treat some copper cylinders in the same way as lead plugs in the foot-pounds machine, and to determine the relation between the work and compression. Having these quantities, the mean resistance is easily obtained by dividing the work expressed in foot-pounds by the compression expressed in feet. This quantity, however, is not what ordnance experts aim at. For their purposes the crucial quantity is the maximum intensity or pressure, supposed to be represented by the maximum resistance of the copper. This we are not so certain of, but will do our best to determine also.

The cylinders were obtained from the Benicia Arsenal. They were .25-inch diameter and .5 inch long. Captain Rockwell, of the

Ordnance Department, had the following scale of pressures determined for me on the testing machine :

Measured Pressures Corresponding to Compression of Copper Cylinders, $\frac{1}{4}$ " x $\frac{1}{2}$ ".

Original length.	Reduced length. Inches.	Compression. Inches.	Pressure. Lbs. on the sq. inch.
.502	.420	.080	21,250
	.412	.090	25,000
	.392	.110	27,500
	.383	.119	30,000
	.370	.132	32,500
	.352	.150	35,000

As a preliminary to my experiments, I prepared a number of weights bearing simple relations to each other, as follows: I took a piece of steel shafting, exactly 2 inches in diameter, and cut it up in a lathe into cylinders 24, 12, 8, 4, and 2 inches in length. I also built a foot-pounds machine specially for these weights.

For my first set of experiments in the foot-pounds apparatus, I selected as my weight the piece of 2-inch steel shafting, 8 inches long, weighing 7.0625 pounds. I found that nearly all the copper cylinders measured within less than $\frac{1}{1000}$ of an inch of .499" in length, whereas Capt. Rockwell gives .502" as their length. This difference was doubtless due to an index error in one of our calipers, but this was unimportant, as the reading of the compression would not be affected thereby.

The following table was made in this way: I dropped the weight from successive heights, beginning with one foot and going up one foot higher each time. At any point where there seemed to be any anomaly in the compression, the experiment was repeated till the doubt was settled. I then began again at 6 inches and went up one foot at a time, so as to get interpolations, anomalies being treated as before. The cylinders proved to be remarkably uniform in their resistance. They retained the cylindrical form very accurately up to a compression of about one-third of their length; beyond this they were barrel-shaped. Under the heavier impacts of the piston a decided rise in temperature was noticed when the little plug was picked up. This was of interest, as the mechanical equivalent of

heat has been determined by this method. I have taken the trouble to calculate the theoretical rise of temperature.*

I made, also, some experiments to determine whether there is any radical difference between copper and lead as registers of work. I found that a copper cylinder, partly compressed, will record a second blow, and even a third or greater number with the same or even greater accuracy than lead. I also proved, by changing my weight, using the 24, 12 and 2-inch pieces of shafting, that the recorded work is independent of the relation of the factors, provided their product is constant—that is, a piston 8" long dropped 2 feet is equal in effect on the copper cylinder to a 2-inch dropped 8 feet. I also proved that the copper is sensitive enough to record a very small work, even when already highly compressed.

If we compare the following table with the data already compiled for lead plugs, we will find that the curve for the copper cylinders falls between the curves for the .75-inch and 1-inch (soft) lead plugs, being nearer the latter; that is, a copper cylinder .25 inches in diameter and .50 inches long gives *about* the same curve as a lead cylinder .93 inches in diameter and 1 inch long. As the sectional areas of the copper and this lead are as 1 to 14, if we take into account the average effect of the difference in length which we can estimate from our general equation, $x = \frac{KALy^a}{L-y}$, which effect increases with the compression, we can say roughly that the ratio of the *sensitiveness* of the two materials to *dynamite* compression is 1 to 10; that is, copper requires ten times as much work as lead to produce equal compressions.

* The calculation of the rise in temperature is made for a fall of 10 feet, giving 70.625 foot-pounds = .09148 British heat units, calling a Joule 772 foot-pounds. The specific heat of copper being .0930, this would raise .9836 pounds (not quite one pound) of copper one degree Fahrenheit. The average weight of the copper cylinders is 3.552 grammes. The number to the pound is 127.7, the number to .9836 pounds is 125.8, which is the number of degrees Fahrenheit this work would raise the temperature of the cylinder. If the primitive temperature were 60°, this would make the temperature of the copper 185°.8, provided, of course, there was no loss. If the crushing were done on a non-conducting surface, the plug would be hot enough to burn the fingers.

The same amount of work would not raise the temperature of the one-inch lead plugs noticeably. Taking their average weight at 145 grammes (40.82 times the copper), the specific heat of lead being .0315, the rise in temperature would be

$$125^{\circ}.8 \times \frac{2.952}{40.82} = 9^{\circ}.09 \text{ Fahr.}$$

TABLE NO. 1.

*First Set Experiments, Copper Cylinders Crushed by Falling Weight.
Weight, 2" Steel Shafting, 8" long, Weighing 7.0625 Pounds.
Copper Cylinders, .25" diameter, .499" long.*

Drop in feet.	Work, foot-pounds (x).	Reduced length of cylinder in $\frac{1}{1000}$ inch.	Compression (y) in $\frac{1}{1000}$ inch.	Mean resistance,, $\frac{x}{y}$
0.5	3.531	465	34	.104
1	7.0625	443	56	.126
1.5	10.594	427.5	71.5	.148
2	14.125	412	87	.162
2.5	17.66	400	99	.178
3	21.187	389	110	.192
3.5	24.72	378	121	.204
4	28.25	367	132	.214
4.5	31.78	357	142	.224
5	35.31	349	150	.235
5.5	38.84	338.5	160.5	.242
6	42.37	331	168	.252
6.5	45.91	323	176	.261
7	49.44	314	185	.267
7.5	52.97	306	193	.274
8	56.50	299	200	.282
8.5	60.03	292	207	.290
9	63.56	285	214	.297
9.5	67.09	280	219	.306
10	70.62	273	226	.312
10.5	74.16	268	231	.321

In this table thousandths of an inch have been treated as whole numbers. It will be noticed that the mean resistance increases pretty regularly with the compression. The curve corresponding to this table will be found plotted on a small scale on Plate III (see Fig. 1). In order to deduce an equation for the curve, I have taken from the latter the following list of new co-ordinates :

y = 25	x = 2.4
y = 50	x = 6.4
y = 75	x = 11.7
y = 100	x = 18
y = 125	x = 25.8
y = 150	x = 35.3
y = 175	x = 45.5
y = 200	x = 57
y = 225	x = 70

These figures have no pretence to minute accuracy, the scale used for the curve being small.

Assuming the equation used for lead plugs,

$$x = \frac{By^a}{499 - y},$$

we calculate the values of B and a by taking the above co-ordinates in sets of two, and find that the curve can be represented pretty accurately by the following simple equation :

$$x = \frac{18y^{1.3}}{499 - y}.$$

The following list of co-ordinates has been calculated from it :

$y = 25$	$x = 2.5$
$y = 50$	$x = 6.5$
$y = 75$	$x = 11.6$
$y = 100$	$x = 18$
$y = 125$	$x = 25.6$
$y = 150$	$x = 35.5$
$y = 175$	$x = 45.8$
$y = 200$	$x = 59$
$y = 225$	$x = 74.8$

The curve represented by the equation is given in Plate III (see Fig. 1). When applied to the first curve the agreement up to a compression of 175 is very close ; beyond this the new curve inclines to the right, but for our present purpose this is immaterial.

Now we will attempt to calculate the maximum resistance corresponding to different compressions, the quantity aimed at in gun experiments. For the range of such experiments the relation between *work* and compression *seems* to be quite accurately represented by the equation

$$x = \frac{18y^{1.3}}{499 - y}.$$

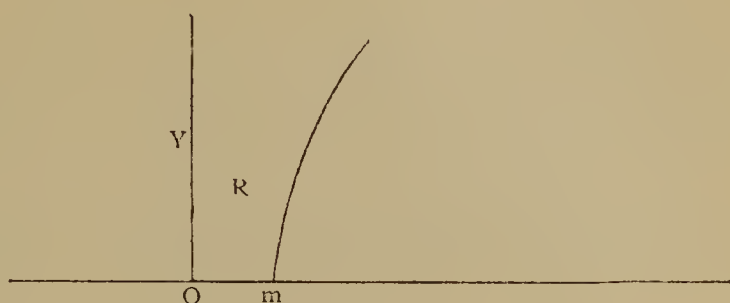
Differentiating this, we have

$$\frac{dx}{dy} = \frac{18 \times 1.3 (499 - y) y^{0.3} + 18y^{1.3}}{(499 - y)^2}.$$

an expression for the tangent of the angle, which this curve makes with the axis of Y .

This curve gives the relation between the work (x), and compression (y).

If we now suppose the curve expressing the relation between the compression (y) and the *resistance* (R) to be constructed, and the initial resistance Om to be equal to R' ,



then the work x will be the area included between the curve and the axis of Y .

Let us assume

$$R = \frac{dx}{dy} = \frac{18 \times 1.3 (499 - y) y^3 + 18y^{1.3}}{(499 - y)^2}.$$

Then since $x = \int R dy$, we have

$$x = \int \left(\frac{18 \times 1.3 (499 - y) y^3 + 18y^{1.3}}{(499 - y)^2} \right) dy;$$

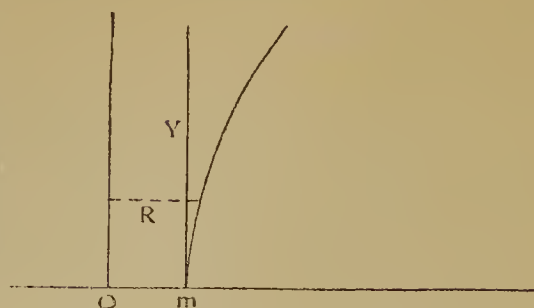
whence
$$x = \frac{18y^{1.3}}{499 - y} + C,$$

which we know to be correct, since the constant C is zero.

But R cannot be equal to $\frac{dx}{dy} = \frac{18 \times 1.3 (499 - y) y^3 + 18y^{1.3}}{(499 - y)^2}$ because this quantity is equal to zero when $y = 0$, whereas R by hypothesis is equal to R' ; so we conclude that the form of our equation $\left(x = \frac{By^a}{L - y} \right)$ is defective for our present purpose. The defect of this form of equation is that it gives a curve *tangent* to the axis of Y at the origin, whereas the curve should make an angle with this axis at the origin, the tangent of which is equal to the initial resistance.

If we consider the work due to the initial resistance and the path separately from the work due to resistances developed by com-

pression and increase of area, and call the latter z , we have $x = z + R'y$, in which z will represent the area included between the R, y curve and a new axis of Y drawn through the point m .



We can determine the values z from the equation $z = x - R'y$, if we know the values R' and x . We can get the values of R' *approximately*, if we have a suitable table of values of x , by determining x when $y = 1$. If we suppose the R, y curve to be a straight line between the origin and this small value of y , then this value of x will be the resistance for $y = \frac{1}{2}$. Moreover, if we can express the value of z by an equation of the form $z = \frac{By^a}{L - y}$, the z, y curve will be tangent to the new axis of Y at the origin, and R for $y = \frac{1}{2}$ will be practically equal to R' for $y = 0$, or R' .

The first step was, therefore, to construct a new table of small values for x . For this purpose I prepared a small foot-pounds machine and used as my weight the 2-inch piston, weighing 1.766 pounds. To insure greater accuracy in measuring the cylinders, both before and after compression, I attempted to divide the $\frac{1}{1000}$ of an inch. In the following table I give the original experiments except a few rejected as failures.

TABLE NO. 2.

Second Set Experiments with Falling Weight (Foot-pounds Machine) on Copper Cylinders. Weight 2" long, 1.766 pounds.

Drop in inches.	Work, foot-pounds (x).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression in ($\frac{1}{1000}$ inches).	Average compression ($\frac{1}{1000}$ inches).	Mean R. $\frac{x}{y}$
$\frac{1}{4}$.0368	499.3	499	.3	.3	.123
$\frac{1}{4}$	.0368	499.7	499.4	.3	
$\frac{1}{2}$	.0736	499.4	498.5	.9	
$\frac{1}{2}$.0736	499.5	498	1.5	1.17	.063
$\frac{1}{2}$	.0736	499.6	498.2	1.2	
$\frac{1}{2}$	.0736	499.6	498.3	1.3	
$\frac{1}{2}$	.0736	499.6	498.6	1.	
$\frac{1}{2}$	.0736	469.5	498.4	1.1	

Drop in inches.	Work, foot- pounds (x),	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compres- sion in ($\frac{1}{1000}$ in- ches)	Average compres- sion ($\frac{1}{1000}$ inches.)	Mean R. $\frac{x}{y}$
$\frac{3}{4}$.1104	499.7	498	1.7	1.57	.070
$\frac{3}{4}$	.1104	499.6	498.2	1.4	
$\frac{3}{4}$	.1104	499.7	498.1	1.6	
1	.147	499.5	497.6	1.9	2.025	.072
1	.147	499.5	497.4	2.1		
1	.147	499.6	497.6	2.0		
1	.147	499.3	497.2	2.1		
2	.294	499.3	494.6	4.7	4.57	.064
2	.294	499.6	495	4.6		
2	.294	499.4	495	4.4		
3	.442	499.2	492.5	6.7	6.6	.067
3	.442	500.1	492.8	7.3		
3	.442	499.2	493	6.2		
3	.442	499.4	493.2	6.2		
4	.589	499.2	490.6	8.6	9.1	.065
4	.589	499	490	9.0		
4	.589	500	490.5	9.5		
4	.589	499.3	490	9.3		
5	.736	499.2	488	11.2	10.95	.067
5	.736	499.	488.3	10.7		
7	1.030	499.5	485.5	14	14.	.074
9	1.324	499.3	481.4	17.9	17.9	.075
12	1.766	499.	476.9	22.1	22.1	.080
15	2.207	499.6	474	25.6	25.6	.086
18	2.659	499	470	29	29.	.092
24	3.532	499	464.5	34.5	34.5	1.02

This table cannot be regarded as a complete success ; according to the theory which we have adopted the mean resistance should be nearly constant for very small compressions and then increase slowly, whereas it begins with a value .123 and then drops to .063. Some importance is to be attached to this latter value as it was the mean result of six experiments. A law of increase in the mean resistance is noticed, beginning at the 2 inch drops ; with some irregularities, it is true, and probably from this point the table is fairly reliable. If we had to decide the question from this table, we would

say that the initial resistance is approximately .063. For the present we reject the data below 2 inches.

For the higher compressions the apparatus worked well, and the accepted data may be regarded as a supplement to the table determined before with the 8-inch piston, with which it connects very well. My next move was to construct a more delicate apparatus—a miniature foot-pounds machine in which the weight was a polished steel cylinder $\frac{5}{8}$ inch in diameter and 3 inches long. The anvil consisted of a steel rod of the same diameter, 15 inches long. The results with this apparatus are given in the following table. I expected great things from it and was proportionately disappointed, as will be seen in due course.

TABLE NO. 3.

Third Set of Experiments with Foot-pounds Machine and Copper Cylinders. Weight $\frac{5}{8}$ " x 3", .259 pounds.

Fall in inches.	Work, foot-pounds (x).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression (y) ($\frac{1}{1000}$ inches).	Average compression ($\frac{1}{1000}$ inches).	Mean R. $\frac{x}{y}$
$\frac{1}{2}$	.01079	499.9	499.8	.1	.1	.108
$\frac{3}{4}$	.01618	499.6	499.5	.1	.1	.162
1	.02158	499.5	499.3	.2	.2	.108
1	.02158	499.6	499.4	.2		
$1\frac{1}{2}$	.03237	499.6	499.4	.2	.2	.162
$1\frac{1}{2}$	.03237	499.7	499.5	.2		
$1\frac{1}{2}$	.03237	499.6	499.6	0.0		rejected
$1\frac{3}{4}$	.03776	499.7	499.4	.3	.3	.126
$1\frac{3}{4}$	.03776	499.7	499.4	.3		
2	.04316	499.8	499.4	.4	.4	.108
$2\frac{1}{2}$	.05395	499.5	499	.5	.5	.108
3	.06475	499	498.4	.6	.65	.100
3	.06475	499.7	499	.7		
$3\frac{1}{2}$	.07553	499.6	498.7	.9	.95	.079
$3\frac{1}{2}$	.07553	499.6	498.6	1.0		
4	.0863	499.2	498.1	1.1	1.1	.078
5	.1079	499.4	498	1.4	1.4	.077
5	.1079	499.5	498.1	1.4		
6	.1295	499.5	497.8	1.7	1.7	.076

Fall in inches.	Work, foot- pounds (x).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compres- sion (y) ($\frac{1}{1000}$ inches).	Average compres- sion ($\frac{1}{1000}$ inches).	Mean R. $\frac{x}{y}$
7	.1511	499.5	497.5	2.0	2.0	.075
9	.1942	499.6	497	2.6	2.6	.075
12	.259	499.4	495.7	3.7	3.6	.072
12	.259	499.5	496.	3.5		
14	.3022	499.8	495.5	4.3	4.2	.072
14	.3022	499.2	495.1	4.1		
16	.3453	499.6	494.8	4.8	4.8	.072
18	.3885	499.2	493.9	5.3	5.3	.073
21	.4532	499	492.8	6.2	6.2	.073
24	.518	499.4	492.3	7.1	7.1	.073
28	.604	499.3	491	8.3	8.4	.072
28	.604	499.5	491	8.5		
31	.669	499.5	490.5	9.0	9.2	.073
31	.669	499.7	490.3	9.4		
35	.755	499.2	489.3	9.9	10.0	.075
35	.755	499.5	489.4	10.1		
38	.8202	499.6	488.9	10.7	10.65	.077
38	.8202	496.6	489	10.6		

In examining this table we are struck with the irregularity of the mean resistance for the smaller drops. This was to be expected, to a certain extent, as the compression below $\frac{1}{1000}$ is, more or less, guessed at. It is curious, however, that the mean resistance should be so large for very small values of x , an anomaly noticed before, to a slight extent, with the 2-inch piston. Below $3\frac{1}{2}$ inches fall the table is valueless. This table should connect with the previous one, but we find that it does not.

In the previous table a compression of 9.2 corresponds to .604 foot-pounds. In this table it corresponds to .669 foot-pounds. The reason, however, is not far to seek. With this light piston there was a decided *rebound*. In some cases the rebound was sufficient to allow the copper cylinder to turn over on its side. This trouble was experienced very slightly with the 2" piston, but was neglected as unimportant. In the present case it vitiated the whole work. The rebound was not uniform. It was decidedly greater on some plugs than on others, when the falls were equal. *It was greater for small*

falls than for large, but could be noticed up to the last. I roughly estimated at about 30 inches fall that the upward rebound was $\frac{1}{4}$ inch. At $1\frac{1}{2}$ inches it was nearer $\frac{3}{8}$ inch. Now what did this rebound mean? Did it mean that the compression was within the elastic limit of the copper and that part of the compression was restored? On this point one experiment is instructive. One of the $1\frac{1}{2}$ falls gave a remarkably high rebound, fully half an inch, and the copper cylinder turned over on its side. The compression was found to be *nil*. To test the cylinders for elasticity I dropped them endwise from varying heights up to about 15 inches upon a steel plate. They rebounded more or less. The greatest height of rebound was estimated at $\frac{3}{8}$ inch. *The miniature foot-pounds apparatus developed individual differences in the copper cylinders, the presence of which was unsuspected.* These irregularities were probably due to the effect of the tool used to turn off the ends. It is necessary to say, however, that these differences would have been insignificant in ordinary work.

The effect of the rebound was to increase the apparent mean resistance, and the results of the table agree with observation. The rebound was greatest for small drops, likewise the values of the mean resistance given in the table. General Abbot, in his experiments with the pendulum hammer on lead plugs, observed a rebound, and corrected the fall by deducting the fall due to the rebound or recoil. I have no doubt he proved this correction sufficient. In the present case, even if I had been able to estimate the height of rebound accurately, it would not have been a sufficient correction. The error is too large. Assuming the data obtained with the 2" piston to be correct, the error averages about $\frac{1}{7}$ of the fall. A very slight rebound was observed at very small heights with the 2" piston. It remained to determine whether the irregularities of this table (page 550) were due to this cause. If by using a heavier piston the average mean resistance were reduced, it would show that the 2" piston was also unreliable.

For this test I selected a piston 4 inches long, having exactly twice the weight of the 2".

TABLE NO. 4.

Fourth Set of Experiments, with Foot-pounds Machine and Copper Cylinders. Weight 4" long, 3.532 pounds.

Fall in inches.	Equivalent fall for 2" weight (inches).	Work, foot- pounds (<i>x</i>).	Original length of cylinder ($\frac{1}{1000}$ inches).	Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compres- sion (<i>y</i>) ($\frac{1}{1000}$ inches).	Mean R, $\frac{x}{y}$	Mean R for 2" weight.
$\frac{1}{4}$	$\frac{1}{2}$	.0736	499.3	498.1	1.2	.064	.063
$\frac{1}{4}$	$\frac{1}{2}$	.0736	499.4	498.3	1.1		
$\frac{1}{2}$	1	.147	499	496.7	2.3	.064	.072
1	2	.294	499.4	495	4.4	.067	.064
2	4	.589	499.1	490	9.1	.065	.065
2 $\frac{1}{2}$	5	.736	499.1	488.6	10.5	.069	.067
3 $\frac{1}{2}$	7	1.030	499.2	485	14.2	.072	.074
4 $\frac{1}{2}$	9	1.324	499.7	482	17.7	.075	.075
6	12	1.766	499.5	478	21.5	.082	.080

In the last two columns I have compared the mean resistance with that of the former table for the 2" piston. It will be seen that there is a substantial agreement, *one table serving to correct the anomalies of the other*. The data of this last table is scanty, but this could not be helped as my supply of cylinders was exhausted. This was regrettable as the apparatus worked very well. No rebound could be detected.

In regard to assuming a figure for the initial resistance the best we can do is to accept .062, which is certainly a very close approximation.

By combining the results of tables Nos. 1, 2 and 4 and constructing a curve on any convenient scale, we can easily get rid of the slight anomalies present. My plan for doing this is to plot all the points given by the tables and prick these on a thin board. With a sharp knife I cut the edge of the board to a curve passing as nearly as possible through these points, and finish the curve with a very small plane and emery cloth. Points which are too prominent are cut away, those which are reëntrant are left inside of the curve. The wooden template, when finished, is used to draw a new curve from which new co-ordinates may be taken. The results of this work are given in the following table.

It was my original intention to obtain the values of *R* by first getting a table of values of *z* from the expression $x = .062y + z$ and

then deducing an equation for the z, y curve of the form

$$z = \frac{By^a}{499 - y};$$

R would then be equal to $.062 + \frac{dz}{dy} = \frac{dx}{dy}$.

But it was essential that the equation $z = \frac{By^a}{499 - y}$ should be reliable for both very small and large values of y . I found great difficulty in fulfilling these exacting conditions, and concluded to abandon the method. My results would have been inaccurate at best.

I obtained the values of R , corresponding to different ordinates, by constructing tangents to the x, y curve at the extremities of the ordinates, and determining the tangent of the angle which these tangents made with the axis of Y —a practical determination of $\frac{dx'}{dy'}$.

The x, y curve for the purpose was drawn on a large scale. I then constructed an R, y curve from the values of R found, and got rid of anomalies as usual. The x, y curve and R, y curve will be found on a reduced scale on Plate III, Fig. 2. (The x, y curve is substantially the same as in Fig. 1.) I have roughly checked the values of R given in the table in several ways. In the first place, it is evident that in a curve of the form of the x, y the tangent of the angle corresponding to a given ordinate as y' , will be greater than the difference between the values of x for $y' - 1$ and y' , and will be less than the difference between the values of x for y' and $y' + 1$. This follows, since the curve continually increases its curvature from the axis of Y .

I give a series of these differences in the values of x in the table for comparison with the values of R .

Secondly, we have a check in the equation

$$x = \frac{18y^{1.3}}{499 - y},$$

from which we have

$$R = \frac{dx}{dy} = \frac{18 \times 1.3 (499 - y) y^{.3} + 18y^{1.3}}{(499 - y)^2},$$

which is quite accurate below $y = 200$, except for very small values of y .

Lastly, I have made a practical integration on section paper of the area between the R, y curve and the axis of x for various ordinates, and compared this area with the corresponding value of x , and

found in every case a substantial agreement. I therefore believe the values of R to be approximately correct.

Table showing Relation between the Work, Compression and Resistance of Copper Cylinders ($25 \times .50$), crushed by a Falling Weight.

y = compression expressed in thousandths of an inch.

x = kinetic energy of the weight (work), expressed in foot-pounds.

R = resistance of the copper expressed in units of 12,000 pounds.

y	x	Difference in value of x for 1 y .	R	Mean R . $\frac{x}{y}$
0	.0		.062	.0
1	.063	.063	.064	.063
2	.128	.065	.065	.064
3	.194	.066	.066	.065
5	.330	.068	.070	.066
10	.700	.074	.078	.070
15	1.10	.080	.090	.073
20	1.57	.094	.102	.078
25	2.13	.112	.118	.085
30	2.80	.134	.135	.093
40	4.34	.154	.156	.108
50	6.05	.171	.178	.121
60	7.98	.193	.200	.133
70	10.10	.212	.222	.144
80	12.42	.232	.245	.155
90	15.00	.258	.268	.167
100	17.85	.285	.290	.178
110	20.93	.308	.311	.190
120	24.24	.331	.329	.202
130	27.70	.346	.348	.213
140	31.28	.358	.365	.223
150	35.00	.372	.382	.233
160	38.90	.390	.401	.243
170	43.00	.410	.422	.253
180	47.30	.430	.444	.263
190	51.80	.450	.467	.273
200	56.53	.473	.501	.283
210	61.65	.512	.538	.294
220	67.25	.560	.577	.305
230	73.42	.617	.620	.319

It only remains to convert the resistances into pounds. Our values of x , numerically equal to the foot-pounds, are really made up of very different units. A unit of work consists of two factors, one representing force—a weight or pressure—the other a path or distance. A foot-pound is equal to twelve pound-inches or twelve-thousandth of an inch. In the present case, the unit of the path being $\frac{1}{1000}$ of an inch, the unit of intensity is 12,000 pounds, the quantity by which it is necessary to multiply the values of R to convert them into pounds. The value of R thus obtained represents the intensity of the force in pounds necessary to produce the corresponding compression of the cylinder (see Table 5, below). Two values are given: one, the mean value, supposes the resistance constant throughout the path; the other is intended to be an actual measure of the intensity of the force or the resistance at the instant of maximum compression.

COMPARISON OF DYNAMIC RESISTANCES AND RODMAN PRESSURES.

To get a comparison of my resistances with the pressures obtained with the Rodman testing machine, I wrote to Captain Rockwell for a more complete table. He sent me a table made by himself, ranging from a compression of .21 to .228; also a very complete table made at Frankford Arsenal, in 1890, for the same cylinders, ranging from a compression of .44 to .260. The agreement between the two is very close, showing that the indications of the testing machine are reasonably positive. The Frankford table is given below. In the original the reduced length of the cylinder only is given. To get the compressions I have assumed the original length to be exactly 500. In the original table the pressure given is “on the square inch.” As the piston used had a sectional area of $\frac{1}{10}$ inch, I have divided these numbers by 10 to get the pressure on the cylinder. Following is the table in condensed form.

TABLE OF PRESSURES ON COPPER CYLINDERS.

Rodman Testing Machine, Frankford Arsenal, 1890. Original Table Abridged.

Reduced length of cylinder ($\frac{1}{1000}$ inches).	Compression ($\frac{1}{1000}$ inches).	Pressure (pounds).
456.4	43.6	1500
451.9	48.1	1600
447.2	52.8	1700
442.3	57.7	1800
438.4	61.6	1880
434.1	65.9	1960
430.2	69.8	2040
426.0	74.0	2120
421.9	78.1	2200
417.6	82.4	2280
413.3	86.7	2360
404.6	95.4	2520
400.2	99.8	2600
389.1	110.9	2800
378.2	121.8	3000
366.8	133.2	3200
356.0	144.0	3400
344.9	155.1	3600
334.1	165.9	3800
323.5	176.5	4000
298.6	201.4	4500
276.8	223.2	5000
257.4	242.6	5500
241.0	259.0	6000

To obtain the interpolations needed for direct comparison with my resistances, I plotted the foregoing data on a large scale and obtained a remarkably regular curve which bears a marked general resemblance to my R, y curve (see Plate III, Fig. 3, in which both are given on a reduced scale). I took the required data from this curve, and it will be found in the last column of the following table, which is a summary of my work on copper cylinders in the foot-pounds machine. (The “dynamic pressure” curve in Fig. 3, Plate III, is the same as the “resistance” or R, y curve in Fig. 2, the abscissas being distorted by the use of a different scale in the two figures.)

TABLE NO. 5.

Table Showing Work, Compression, and Resistance of Copper Cylinders Compressed by a Falling Weight; also Rodman Pressures.

Compression (y) ($\frac{1}{1000}$ inches).	Work (x) (foot-pounds).	Resistance, final intensity of force (R) (pounds).	Mean resistance ($\frac{x}{y}$) (in foot-pounds).	Rodman pressures (Frankford) (P) (pounds).		Ratio ($\frac{R}{P}$)
1	.063	768	756	510	} hypothetical, taken from curve. }	1.5
2	.128	780	768	.....		.....
3	.194	792	776	.....		.....
5	.330	840	792	.....		.....
10	.700	936	840	720	} hypothetical, from the curve. }	1.3
15	1.10	1080	880	840		1.3
20	1.57	1224	942	955	Rockwell.	1.3
25	2.13	1416	1022	1070	"	1.3
30	2.80	1620	1120	1200	"	1.3
40	4.34	1872	1302	1410	Frankford.	1.3
50	6.05	2136	1452	1630		1.3
60	7.98	2400	1596	1845		1.3
70	10.10	2664	1731	2045		1.3
80	12.42	2940	1863	2240		1.3
90	15.00	3216	2000	2420		1.3
100	17.85	3480	2142	2605		1.3
110	20.93	3732	2283	2795		1.3
120	24.24	3948	2424	2975		1.3
130	27.70	4176	2557	3145		1.3
140	31.28	4380	2681	3325		1.3
150	35.00	4584	2800	3505		1.3
160	38.90	4812	2919	3690		1.3
170	43.00	5064	3035	3870		1.3
180	47.30	5328	3153	4060		1.3
190	51.80	5604	3272	4265		1.3
200	56.53	6012	3391	4460		1.3
210	61.65	6456	3523	4660		1.4
220	67.25	6924	3668	4875		1.4
230	73.42	7440	3831	5110		1.4

In the above table the "Rodman pressures" (5th column) below a compression of 20 are hypothetical—obtained by prolonging the

curve. Between 20 and 40 they are from Captain Rockwell's data. Comparing the "resistances" with "pressures," there is no close agreement, but a constant ratio of 1.3 between the two, except near the two extremes of the table, and there the ratio is either 1.4 or 1.5 (compare curves on Plate III, Fig. 3). This result, when it is considered by what very different methods the two series of numbers were obtained, is certainly remarkable.

LOW AND HIGH FORMS OF COPPER RESISTANCE.

It appears from this that the resistances developed in the falling weight machine are uniformly about 1.3 times the pressures as determined slowly in the Rodman testing machine. Both are intended to measure the intensity of the force which is in equilibrio with the copper resistance corresponding to a given compression. Which is right? Probably both; that is, the resistance of the copper varies with the circumstances of the compression. It offers greater resistance when the compression is hurried, and less when the compression is slow. In this respect, therefore, copper resembles lead. The difference between them is one of degree only, as we predicated upon *a priori* principles. In lead we have seen that the property is so marked that a practicable scale cannot be made with the testing machine. To support our reasoning we bring to our aid the authority of Prof. R. H. Thurston, one of the members of the celebrated U. S. Board for testing metals, which a few years ago discovered and formulated the *law of the elevation of the limit of stress of iron*. Prof. Thurston found that copper, tin and lead formed a class of metals opposite in their qualities to iron. They have no elevation of the limit of stress, but oppose increased resistance to sudden strains and a lessened resistance to slow strains.

The only other investigator in this special field is General Abbot. He made a comparison of pressure and shock upon copper discs, using Rodman's indenting piston—not the curved, but the angular or pointed cutter, the angle being $163^{\circ}30'$ made by the two parts of the wedge. He concluded that the Rodman pressures should be taken to represent *mean*, not *maximum* pressures. By subjecting the discs and piston to the action of his pendulum, and dividing the kinetic energy or (work in foot-pounds) by the indentations (depths of cut expressed in feet), he obtained numbers which compared well with the pressures of the Rodman tables. On page 28 of his Report he gives a table of his results. In regard to this he

says: "The last two columns show a surprising correspondence between scales of absolute pressure obtained by methods so radically different as those of Rodman and my own. . . . The comparison of the two methods certainly tends to confirm the practical value of the Rodman scale, except, perhaps, for low pressures."

General Abbot's work certainly proves that for the double wedge cutter, or indenting tool, the Rodman pressures are practically equal to the *mean* resistances developed by a blow. This is an interesting and surprising result. In the compression of the cylinders we have seen that the Rodman pressures are directly proportional to the *maximum resistances* developed by a blow and bear no simple relation to the mean resistances. I have thought it worth while to make a comparison between the maximum resistances and the Rodman pressures for the double wedge cutter also.

COMPARISON OF DYNAMIC RESISTANCES AND RODMAN PRESSURES FOR THE POINTED CUTTER PISTON OR INDENTING TOOL.

For this purpose I use the data of General Abbot's table. I first plot a curve on a large scale using the work (W) expressed in foot-pounds as abscissas, and the computed indentations (I) expressed in $\frac{1}{1000}$ of a foot as ordinates. I then construct tangents to the curve at the extremities of the ordinates, and determine the tangents of the angles which these make with the axis of Y . These values of the tangents, multiplied by 1000, are the maximum resistances (or the resistances corresponding to the tabular indentations) expressed in pounds. As the accuracy of the results is a question of construction, I check the values of $\frac{R}{1000}$ thus obtained by plotting a new curve (R, I curve), using these values as the abscissas and the indentations as ordinates. From this new curve I take my final values of $\frac{R}{1000}$. I have checked these by practical integration of the R, I curve, as well as by comparison with successive differences in the value of the work. I therefore believe my results fairly accurate. Luckily, in this case, I can check them absolutely, though I must frankly admit that this was an after thought. During the course of my work I noticed with interest that the W, I curve was evidently tangent to the axis of Y at the origin; also, that the R, I curve passed through the origin. That is, the initial resistance is zero, which is reasonable, in view of the sharp point on the cutter. I

then began to cast around for an equation for the W, I curve, when I found it staring me in the face, General Abbot having already deduced it ; in fact, he uses it to compute the indentations.

The equation is $I = .002156 W^{\frac{1}{3}}$, whence $W = \frac{I^3}{.002156^3}$, in which W is the work in foot-pounds, and I is the path or indentation in feet.

If we let R equal the resistance in pounds, we have

$$W = \int R dI.$$

Differentiating, we have $R = \frac{dW}{dI}$,

and applying this to the equation above,

$$R = \frac{3I^2}{.002156^3}.$$

From this, by substituting for I the tabular indentations, we can deduce the absolute values of the corresponding resistances.

I have concluded to let my values deduced by the graphic method appear in the table also, though the only purpose they serve is to show what accuracy can be expected by an unskilled draughtsman in using this method.

RODMAN TESTING MACHINE AND PENDULUM HAMMER.
Comparison of Pressure and Shock on Copper (Indenting Tool).

Kinetic energy of pendulum (W) work.	Copper indentations computed (I).	Rodman pressures (P).	Mean resistance ($\frac{W}{I}$).	Max. resistance (R), graphic methods.	Max. resistance, $R = \frac{dW}{dI}$.	Ratio ($\frac{R}{P}$)
Foot-pounds.	Feet.	Pounds.	Pounds.	Pounds.	Pounds.	
0.226	.00131	285	172	490	514	1.8
0.630	.00184	533	340	970	1,013	1.9
2.496	.00292	1,180	855	2,550	2,552	2.16
5.532	.00380	1,880	1,451	4,350	4,323	2.3
9.743	.00460	2,584	2,116	6,200	6,334	2.45
14.860	.00530	3,315	2,803	8,200	8,409	2.54
21.290	.00597	4,040	3,566	10,300	10,669	2.64
28.930	.00662	4,867	4,371	12,950	13,119	2.69
37.370	.00721	5,660	5,186	15,500	15,561	2.75
46.800	.00777	6,463	6,025	18,000	18,072	2.79
57.000	.00830	7,280	6,872	20,600	20,622	2.83
67.980	.00880	8,110	7,725	23,500	23,181	2.86
79.610	.00927	8,890	8,590	26,300	25,724	2.89

The first four columns of the above table are taken from General Abbot. The other three columns are mine. The last column gives the ratio $\left(\frac{R}{P}\right)$ of the maximum dynamic resistances to the Rodman pressures. It will be noticed that this ratio is not constant, as in the case of the copper cylinders, but increases for the limits of the table from about 1.8 to 2.9 (see curves, Fig. 4, Plate III).

The table shows that General Abbot's point in regard to a substantial equality between the Rodman pressures and the *mean resistances* $\left(\frac{W}{I}\right)$ is well taken. We must regard this in the light of a coincidence which results from the form of the cutter. If we interpret these results by the light which we have already obtained on the subject, it appears that the resistance R developed by a blow is greater than the resistance P developed by pressure, and that the ratio $\left(\frac{R}{P}\right)$ between these quantities increases with the indentation. This results from the form of the cutter. The initial resistance is zero for both applications of force, so that this ratio must begin as an equality, or 1, and increase to its limiting value, which appears to be beyond the confines of the table.

In the cylinders, on the contrary, there is a well-defined initial resistance for both applications of force, and the ratio $\left(\frac{R}{P}\right)$ may and does hold a constant value from the beginning.

The form of indenting tool or Rodman cutter, now generally used, has a curved edge, usually the arc of a circle. I have no data at hand to determine its properties under the action of a blow or falling weight, but think it will develop a very small initial resistance. Otherwise its action will closely resemble that of the cutter used by General Abbot.

APPLICATION TO EXPLOSIVES.

It will be noticed that we have been careful so far to say as little about the intensity of the acting force as possible. We will now explain why.

From the standpoint of the artillerist, a given compression or indentation indicates that a certain pressure has been exerted, or a force has acted with a certain intensity. Having regard to the

whole field of explosives, we prefer to say that a certain amount of work has been done. A force has acted in producing this work, and the *final* intensity of this force is represented by the artillerist's pressure, or by our resistance, depending upon whether the force has acted slowly or quickly. In either case final intensity is the only intensity measured.

CASE OF FALLING WEIGHT OR IMPULSIVE FORCE.

The case of a disc indented or cylinder compressed by a blow or falling weight has some features of its own, and differs from the general case of work by an explosive; nevertheless, as it has been used to prepare our tables, we may get some light by discussing it.

What is the intensity of the force in this case? Evidently the measure we aim at is the intensity of the force at the moment of contact. This is strictly analogous to an explosive which delivers its blow in one impulse; but, as no explosive acts in this way, though the fulminates may approximate it, we see that we are dealing with a special problem. In the practical case of using the gauges to determine *the action of an explosive*, the record enables us to determine the *final* resistance of the copper only, which is equal to the final intensity of the force.

We know nothing of the intermediate history of the force from the beginning of its action to its close, except that its intensity at any intermediate point must have exceeded the corresponding copper resistance in order to overcome it. The law of variation in the intensity of the force during the time of action, so far as the record of the work discloses it, is a sealed book.

The work relates only to the *resistance* and the *path*. The intensity of the force may have been greater in the beginning, and diminished to an equality with the resistance which limited the path; it may have been constant throughout; or it may have increased during the period of action, but less rapidly than the resistance. The record on the copper furnishes us no data for determining the nature of the change. It gives the intensity at one point only, and even this must be obtained by an intelligent interpretation of the record.

In regard to the *mean intensity*, this, to my mind, is a conventional quantity that has no application as a measure of the force in

this case. To use it as such is to assume that the force is in equilibrium with the resistance at every point, and that its intensity is an average of the resistances; but we know that the intensity of the force must be greater than the resistance at every point except one, at which it is just equal to it. Mean intensity obtained by dividing the work by the path is, therefore, misleading, and bears no necessary relation to the force.

Returning to consider our special case, that of a falling weight, what is the intensity of the force corresponding to a given record? The measure we desire is the maximum intensity which coincides with the beginning of the action.

We know that the kinetic energy or work is equal to $\frac{1}{2} \frac{WV^2}{g} =$

Wh , in which W is the weight of the falling body, V its velocity at the moment of impact, h the height of fall, and g the velocity impressed by the force of gravity in the unit of time. This energy is transferred to the piston or cutter, which is thus animated with a velocity that will cause it to describe a path shorter or longer, depending upon the resistance encountered.

The intensity of the force will diminish during the description of the path, and the path will end when the resistance encountered is equal to the diminished intensity of the force.

To throw further light on the subject I have prepared a new table comparing the final intensities of the force in the two cases of the indented discs and compressed cylinders for the *same work*. This table has been compiled from previous tables by graphic interpolations. The paths (indentations or compressions) are given in feet, also the mean resistances, obtained by dividing the work by the path. (See p. 567 for table.)

This table serves to show the relation between the three quantities, work, resistance, and path, for both cylinders and discs under the action of a falling weight. We can easily see by a study of this table that the only measure of the force is the work. Final intensity, as deduced from the record, is a *term related to previous resistances and the length of the path*. To illustrate:

1 foot-pound expended in indenting the copper disc shows a final intensity for the force of 1075 pounds.

1 foot-pound, in compressing the cylinder, shows also 1075 pounds final intensity, the ratio being 1:1.

60 foot-pounds on the disc shows a final intensity of 19,850 pounds. The same energy expended on the cylinder shows only 6300 pounds, the ratio being 3:1.

Nor does the mean intensity—work divided by the path—give more consistent figures.

1 foot-pound on the disc gives a mean intensity of 476 pounds.

1 foot-pound on the cylinder gives 860 pounds, the ratio being 1:1.8.

60 foot-pounds on the disc gives 7109 pounds mean intensity.

60 foot-pounds on the cylinder gives 3478 pounds, the ratio being 2:1.

This shows that no reliable absolute figure for the intensity of the force can be obtained in this way, since by using a very high resistance and restricting the path the intensity can be indefinitely increased. The table, moreover, shows that no reliable *relative* figure can be obtained, for one column of resistances is just as reliable as the other, and they are inconsistent with each other.

*Relation between Work, Resistance (Final Intensity), and Path.
Compression and Indentation of Copper by a Falling Weight.
(Rodman Pointed Cutter Used for Indentation.)*

Work (<i>W</i>) foot- pounds.	Indentation of copper discs.		Compression of copper cylinders.		Discs.	Cylind'rs	Relative inten- sity $\frac{1}{\sqrt{W}} \times 1000.$
	Path.	Final inten- sity of force.	Path.	Final in- tensity of force.	Mean re- sistance.	Mean re- sistance.	
	Feet.	Pounds.	Feet.	Pounds.	Pounds.	Pounds.	Pounds.
0.1	.00100	250	.000132	770	100	760	316
0.2	.00125	450	.000258	780	160	776	447
1.0	.00210	1,075	.00116	1,075	476	860	1,000
2.0	.00271	2,100	.00198	1,400	738	1,010	1,414
5.0	.00365	4,100	.0036	2,000	1,370	1,390	2,236
10.0	.00463	6,560	.0058	2,610	2,160	1,724	3,163
20.0	.00587	10,360	.0089	3,630	3,407	2,247	4,472
30.0	.00672	13,500	.0114	4,280	4,464	2,631	5,477
40.0	.00748	16,270	.0136	4,900	5,348	2,941	6,325
50.0	.00794	18,540	.0156	5,490	6,297	3,205	7,071
60.0	.00844	19,850	.0173	6,300	7,109	3,478	7,746
70.0	.00889	23,650	.0187	7,160	7,874	3,743	8,367

The use of mean resistance to measure the intensity of a force and its dependence on the path may be illustrated by two diagrams

of work, equal rectangles, of which the vertical dimensions represent intensity, and the horizontal dimensions represent path, thus :



It may be asked, Is there any way of getting a measure for the intensity of the force?

I think a *relative figure* of some value may be obtained by extracting the *square root of the work*.

The falling body, striking with a velocity V , may be taken to represent a motive force. The intensity of a motive force is measured by the product of the mass moved by the velocity generated during the time of action divided by the time, the force being supposed constant during the time of action. If this time is very short this last condition is immaterial. The motion of the falling body is arrested by the resistance of the copper in an interval of time so short that it cannot be measured.

We can get a clear idea of the intensity of the force embodied in our falling weight at the instant of impact by supposing the action reversed. After the compression or indentation has been completed, let the original form and temperature of the copper be suddenly restored, so as to reverse the circumstances of the action and generate in the falling body the velocity of V in the same short interval of time, and throw the body to the height h : The intensity of the force exerted will be measured by $\frac{MV}{t}$, in which M is the mass, V the velocity of the falling body, and t the short interval of time.

Let us suppose this interval of time to be practically the same throughout the range of the experiments; this is rendered probable by the following considerations.

If the interval of time varies it will affect the resistance of the copper and, consequently, the recorded work.

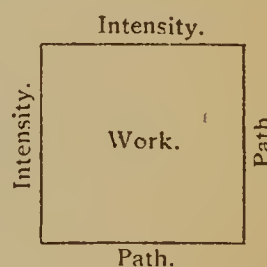
But it must be independent of the weight of the body, since we get the same record of work using different weights.

It is also independent of the height of fall, since we get the same record of work from different heights.

It follows that it is either independent of both, that is, constant, or exactly proportional to the work. But if it is proportional to the work, the formula $\frac{MV}{t}$ will give greater intensities for smaller velocities, which is absurd. The conclusion is that it is constant. Then the relative intensity will be measured by MV , and, since the mass is constant, by V , which is proportional to the square root of the work.

If this reasoning in regard to the interval of time t is unsatisfactory to the reader, then we fall back upon this simple consideration: The interval is so short that the force of restoration of the copper which will give the velocity V to the weight may be considered an *impulsive force*, the intensity of which, according to the mechanicians, is measured by MV —the quantity of motion generated during the *whole* time of action.

The use of the square root of the work to represent the intensity of the acting force is illustrated by a diagram of work, a square, in which either dimension may be considered intensity, and the other the path. In advocating the foregoing opinions, I am sorry that I do not agree on one important point with General Abbot, whose general views have had much to do with forming my own.



General Abbot regards the work registered by the gauge as the integral of the product of the force intensity into the differential of the path; consequently, he concludes that the mean pressure or intensity may be obtained by dividing the work by the path. He applies this alike to explosive mixtures and detonating compounds. It is true that he recognizes the arbitrary nature of his unit of intensity derived from copper indentations, and, moreover, shows that his final conclusions are independent of it. We also note his great need of an *absolute* unit of intensity, which he could obtain only by setting up an arbitrary test. Nevertheless, it is unfortunate that his table of intensities should be quoted as a classic by all writers on the subject, most of whom do not recognize the arbitrary nature of this unit. Perhaps it is unfair to hold General Abbot responsible for this.

While the available energy of the explosive (in the case of detonating compounds) is directly proportional to the charge, and

inversely proportional to the square of the distance (nearly), the intensity of action (mean pressure), *as a result of adopting this particular measure for it*, varies directly with the two-thirds power of the charge, and inversely with the 1.4 power of the distance.

If he had chosen to adopt the square root of the work as the relative intensity, the intensity of action would have varied as the square root of the charge, and inversely as the distance.

The point in which we differ is this: he regards force intensities as being in equilibrio with resistances. From one point of view he may be right. There are often two ways of looking at a question in mechanics; both may be right, but one may be objectionable on account of the train of consequences.

It is quite usual to speak of work as the product of the effort into the path (see Bartlett's *Synthetical Mechanics*, page 49), or the product of a force intensity into a path; but, strictly speaking, it is better to regard work as the product of a *resistance* and a path. The habit of regarding resistance and force intensity as equivalents is drawn, I think, from Watt's diagram of work, in which a curve limits the ordinates representing the varying pressures of a gas. The external work done by the gas is the area included between the axis of abscissas, the curve, and the extreme ordinates. But the fundamental condition is that all parts of the gas shall be at the same pressure (see Tait's *Thermodynamics*, page 87), which is equivalent to saying that it is in equilibrio throughout, and, consequently, in equilibrio with the resistance.

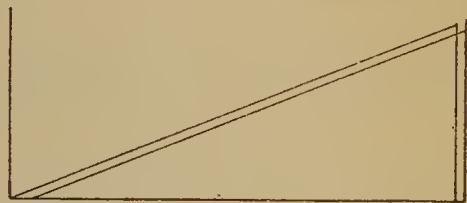
In the general case, the force intensity is not in equilibrio with the resistance when performing work. To consider it so is to attach no useful meaning to the term intensity. In the case of work on the copper cylinders or discs, to consider it so gives the force its greatest intensity at the moment it ceases to work.

A weight falling from a certain height represents a certain force, the intensity of which should be a property of the force itself. But if the force be allowed to work we can get any intensity we please by this rule. By extending the path we reduce the intensity; by limiting the path we can increase it indefinitely. But, if force intensities are sometimes in equilibrio with resistances and sometimes not, where do we draw the line? It is true that forces are always in equilibrio; that is, we can find for every acting force a counterpart equal and contrary in direction. But to do this for every case, we

must sometimes consider inertia. When inertia is not considered, that is, when the motion is so slow that we may neglect it, or when the work of inertia is balanced by minus and plus work, we can safely deduce the work of the acting force from the force intensity and the path; or, reversing the operation, deduce the intensity from the work and path.

We have elsewhere said that a force intensity must always exceed a resistance to overcome it. How then, in *any case*, can the integral of the product of the force intensity into the differential of the path give the same result as the integral of the product of the resistance into the same differential?

Mechanics is filled with just such paradoxes. The difference in this case between force intensity and resistance is very slight and is not cumulative. The paradox may be illustrated by the following diagram, in which two equal triangles, almost exactly superposed, represent—one the work as deduced from the intensity, the other from the resistance.



To show what forces are in equilibrio during the compression or indentation of the copper by a falling weight, let us resume our hypothesis that, at the instant of maximum work, a force of restoration reproduces the original form and temperature of the copper, exactly reversing the circumstances of the direct action. Let us suppose the path to be divided into a number of elementary paths corresponding to a series of elementary times.

The force of restoration, now the acting force, will have an initial intensity or pressure equal to the final copper resistance in the direct action. This intensity corresponds to the first elementary time, and would, if it remained constant, generate in the body in the unit of time a quantity of motion equal to itself. The acting force will be in equilibrio with the force of inertia. During the next elementary time the force will have a slightly less intensity, which would generate in the unit of time an equal quantity of motion. The force of inertia again opposes an equal and contrary reaction, and so on, through all the elementary times.

Now let the elementary path be ds , and the elementary time dt .

The intensity of the force at any point will generate a velocity V , which may be regarded as constant during the elementary time dt ,

during which the body will describe uniformly the elementary path ds . Hence we have

$$V = \frac{ds}{dt}, \text{ or } ds = Vdt; \quad (1)$$

The intensity of a motive force, or the inertia it will develop, is measured by the quantity of motion which it can generate in the unit of time, the intensity remaining constant for that time. The intensity of the force will vary, in this case becoming less and less. However, we may regard it as constant during the elementary time dt , during which it generates a velocity dV , and were it to remain constant it would generate in the unit of time a velocity $\frac{dV}{dt}$.

Denoting the varying intensity by R , we have, therefore,

$$R = \frac{MdV}{dt}, \quad (2)$$

or,

$$R = M \frac{d^2s}{dt^2},$$

that is, the intensity of the acting force, or the inertia which it develops, is equal to the product of the mass moved into the velocity impressed in the unit of time, or more simply, the mass into the *acceleration*.

Multiplying equations (1) and (2) together, we have

$$Rds = MVdV, \quad (3)$$

from which, by integration, we get

$$\int Rds = \frac{MV^2}{2}.$$

The first number is the work of the force equal to that of the inertia; the second, the kinetic energy of the body as a result of this work.

Returning to the direct case of compression or indentation by the falling body, we see that the copper resistance at every point is in equilibrio with the *successive decrements* in the quantity of motion of the body; or, what is the same thing, it is in equilibrio with the inertia developed. We now see the sense in which the force intensity and the resistance may be considered in equilibrio, the point of view which General Abbot adopts. *It is that portion of the intensity which is called into play to overcome the resistance.* The intensity

not called into play for the time being *may* be considered as pertaining to *potential* energy.

The foregoing demonstration, if it may be considered such, has not the slightest claim to originality. It is taken almost bodily from that grand old book, Bartlett's Analytical Mechanics.

STRENGTH OF EXPLOSIVES.

We make a short digression to consider a subject which has engaged the attention of many practical men. *What is the proper measure of the strength of an explosive?*

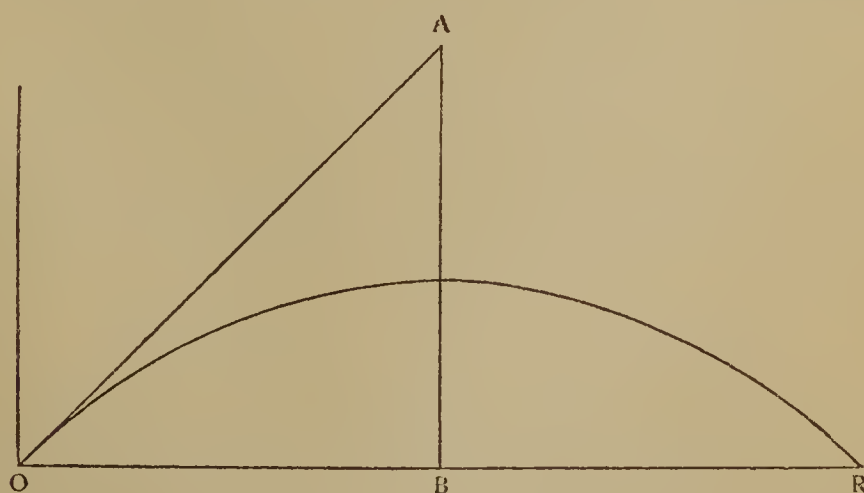
For commercial purposes there can be but one answer. Strength in this sense is a question of dollars and cents. When the miner buys dynamite he buys power; that is, something capable of doing work.

The proper measure is one which makes two pounds of the explosive twice as strong as one pound.

Let us see whether this is the compression of a lead or copper cylinder, intensity (mean or final), velocity given to a shot, or what not.

We will first consider the mortar or éprouvette, a very short gun, fixed at an angle of elevation of 45° , and throwing a heavy shot short distances, usually less than 1000 feet.

It was long ago observed that two ounces of gunpowder gave twice the range of one ounce. The rule holds with even greater exactness in the case of dynamite or other high explosive. The range is, there-



fore, the proper measure. The range being short and the shot heavy, atmospheric resistance may be neglected, and the trajectory be considered a parabola.

The height h , due to the initial velocity V , is equal to AB , but the angle of projection being 45° , OR , the range, is equal to twice AB , hence $V = \sqrt{2hg} = \sqrt{Rg}$, R being range or $V^2 = Rg$; hence the work $\frac{1}{2} MV^2 = W. \frac{1}{2} R$, in which M is the mass and W the weight of the shot. From which we see that the range is proportional to the work.

The only other measure we can consider in this case is the *intensity* of the force of projection, which is measured by the product of the mass moved into the velocity generated during the time of action divided by the time. The force is assumed to be constant during its action, and the time we can only guess at. The best we can do is to assume the intensity to be measured by the product of the shot's mass by the initial velocity, or MV , which is equal to $M\sqrt{Rg}$. This measure is based upon the velocity imparted to the shot; the other on the square of this velocity. It is needless to say that the latter measure is right and the other wrong.

To confirm our assertions we could give numerous examples of mortar experiments taken from my note books, but we trust the reader will take our word for the fact that, deducting the range due to the cap, the range of dynamite or other high explosive is very exactly proportional to the charge.

In a similar way we could show by notes of actual experiments that the work of a high explosive in the crusher gauge, as deduced from our curves, is likewise proportional to the charge. In fact, so accurate is this principle that it may be used to check a new curve or extend an old one.

We, therefore, think that the *strength of an explosive should be considered as measured by its available energy, or the work it is capable of doing under some test capable of measurement.*

In this we are not laying down any new principle, but one which has sometimes been ignored. General Abbot, however, gives it full recognition.

APPLICATION TO HIGH EXPLOSIVES.

So far our discussions have been chiefly concerned with the test of explosives which are too quick in their action to have the Rodman method applied to them. We can sum up this part of our subject as follows: When the crusher or cutter gauge is used, the work and its elements, path and resistance, must be measured by a *dynamic* scale;

that is, a scale determined by the sudden application of a force. The only method so far adopted for preparing such a scale is that of the pendulum or falling weight.

This application of force develops the highest form of copper or lead resistance; consequently, a given compression or indentation will denote a greater work than the same compression or indentation by the Rodman scale, in which the low form of copper or lead resistance figures. We have shown that in crushing the copper cylinders ($.25'' \times .50''$), by the two methods (measure and shock), these two resistances bear nearly a constant ratio of 1 : 1.3.

In the indentation of copper discs by the pointed cutter, the ratio between the low and high form of resistance increases with the path from about 1.8 to 2.9 for the limits of our data.

The ratio of these two forms of resistance, in the case of *lead*, is much larger than in copper, as shown by General Abbot; indeed lead resistance is so sensitive to change in this regard that General Abbot found it difficult, if not impossible, to establish a satisfactory Rodman scale of pressures for it.

We can say, therefore, that *lead is only suited to the dynamic scale*.

Now, keeping in mind this fact of a change in the nature of lead or copper resistance depending upon the time consumed in the application of the force, we see that the *actual* work done by an explosive may not be the same as the work or kinetic energy of the falling weight, set down in our tables as corresponding to the compression or indentation, because the explosive may be slow enough to develop a lower resistance than that encountered by the falling weight.

The error is liable to be much larger with lead than with copper, and so far as this argument goes, copper is the better of the two materials, and the cylinders better than the discs; since, in the cylinders, the extreme variation in the resistance is only from 1 to 1.3. We can usually determine from outside considerations whether the explosive is liable to excite some intermediate form of resistance.

We had in the experiments with the water crusher gauge a striking example of the effect of *prolonged action* of the explosive upon lead; but this was the result of an accident, the gauge no longer acting as such but as a mortar. In testing explosives the sensitive nature of lead resistance renders it essential that there should be an instant release of the gases, which is secured by the construction of both the

Drinker and Quinan gauges, otherwise the dynamic scale would not apply.

Practical observation in testing explosives, both with the crusher gauge and mortar, has given rise to a belief, which may be stated as a paradox, though it hardly rises to the dignity of a scientific fact. It is this: Among slow explosives, or explosive mixtures, the one that makes the best "showing" is the quickest one. Among quick explosives, or detonating compounds, the one that makes the best "showing" is the slowest one.

Taking this rough statement for what it is worth, it is not without reason to support it. To overcome a given resistance and perform work, a certain intensity or rapidity of action is necessary, but if the action is more rapid than necessary it creates difficulties for itself.

If two detonating explosives are equal in chemical attributes, I think the slower of the two will make the best record; that is, give the greatest compression in the crusher gauge. They may have *actually* performed the same work, but the quicker one will encounter a higher resistance and give less compression, consequently. In such a case the question could be decided by measuring the heat developed in the plugs, practically a difficult matter.

By chemical theory the advantage of blasting gelatine over nitro-glycerin is very slight, but it makes a decidedly better "showing" in the gauge. I think it is very slow as a detonating explosive, but have no absolute method of proving it. The question whether or not the "showing" in the crusher gauge, as dependent on the relative slowness or quickness of high explosives, represents a real advantage in certain blasting operations, would depend upon the law of change in the particular resistance encountered. If, like copper and lead resistance, it increased with rapidity of action, the advantage would be real. If, on the contrary, it decreased with rapidity of action, the advantage would be unreal. Where a large part of the work consists in moving heavy masses of material, the advantage would be real, as inertia is a resistance which increases with rapidity of action. Where, on the contrary, the breaking of hard rock constituted the chief element of the work, I think the advantage would be unreal.

To illustrate, it has been found that for breaking boulders by surface action, blasting gelatine is inferior to dynamite, being, as I take it, too slow for the work.

CRUSHER AND CUTTER GAUGES IN GUNS.

The question at issue here is whether the record of the gauge is to be interpreted as a record of work or a record of pressure.

According to the artillerist, it is a record of maximum pressure. When the record is made in the testing machine it may be considered indifferently a record of either work or pressure.

Let us first consider this operation. The motion of the point of application of the force is so slow that inertia may be neglected, and the pressure and resistance be considered equal. The force develops the low form of copper resistance. Even if we attempt to apply the force suddenly and develop a higher form of resistance, this passes into the low form before we can measure it, the copper yielding enough to establish an equality between the pressure and the low form of resistance. The work is, therefore, the integral of the product of the varying pressure into the differential of the path.

The argument that the gauge record is a record of the highest pressure in the gun is this: a certain path corresponds to a certain maximum pressure, because any pressure less than this will not overcome the resistance up to this point, and any pressure greater than this will overcome the resistance beyond this point, and so extend the path. This reasoning assumes that the action of the powder gases is substantially like that of the testing machine.

In regard to the action of powder in guns, the celebrated English Committee on Explosives said something as follows. I quote from memory, and if the Committee did not say the equivalent of this I will father it myself.

“When a charge is lighted in a gun the pressure rises rapidly to a point a little below the maximum, then more slowly to the maximum at which epoch the shot has just moved. The pressure then falls more or less rapidly, depending upon various circumstances.”

We will assume, for the sake of argument, that the time required to give a certain compression or indentation in the testing machine and the time of action of the powder gases in the gun are equal.

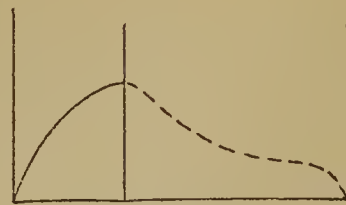
The Rodman theory of the crusher gauge may be illustrated by two rough diagrams, one of which represents the action of the testing machine, the other the action of the powder gases (page 578).

The ordinates represent pressures, the abscissas, times. Neither is a diagram of work; both are diagrams of pressure as related to

time. The powder pressure is only effective in making the record during its passage from zero to maximum, consequently the latter part of the powder curve is dotted.



Testing Machine.



Powder Gases.

The diagrams for the cutter gauge present no differences from the above which make it worth while to specially consider them.

We think this presents the Rodman view very fairly. The argument is plausible. Moreover, it is supported by General Rodman's experiments, also by the English experiments, before alluded to, in which a copper cylinder, compressed by a charge of powder, was used over and over again for the same test without undergoing further shortening.

When I started this discussion I stated my belief that the record of the Rodman gauge was a record of work. That was prejudging the case, but that belief, like any other I may hold, is subject to correction. General Abbot, who is an advocate for work also, makes in this connection a very shrewd remark. He asks: "Why should further motion be communicated to the indenting tool when supported by a surface cut in the copper, which has resulted not only from the maximum action, but from the combined effect of all other actions?"

Having presented the argument for pressure, perhaps the fairest way is to present as strongly as possible the argument for work, reconciling the two views as best we may. We have already seen that working forces present two distinct cases.

The first is the case of a force working so slowly that inertia is not concerned—the resistance it develops at any instant is practically in equilibrio with it. I say practically because the equality is only approximate. If there is absolute equality at any instant the work ceases. This is the case of work in the testing machine. Its characteristic is the absence of kinetic energy. The work is an incidental. The record is a record of pressure.

The second case is that of a dynamic force proper, which is typified by a body moving with a certain velocity and possessing a kinetic energy depending upon this velocity and the body's mass—

that is, it is capable of doing a certain amount of work, and, moreover, it *must* do that amount of work and no other.

Now, the pressure of the powder gases is a static force so long as it does no work, or works so slowly that there is a continuous practical equality between pressure and copper resistance, but it *may* be transformed into kinetic energy by giving motion to the piston.

In the general case, is this force applied gradually as in the testing machine, or do the gases launch themselves against the piston and drive it into or against the copper?

Assuming the circumstances of the action to be given correctly by the latter statement, at or near the beginning of the motion, the powder pressure in running up to its maximum exceeds the corresponding copper resistance. Having received its maximum it will fall more or less rapidly, but the piston will continue to move, notwithstanding that the resistance may then exceed the powder pressure. The energy in excess at the beginning fills the deficiency in the latter part of the path.

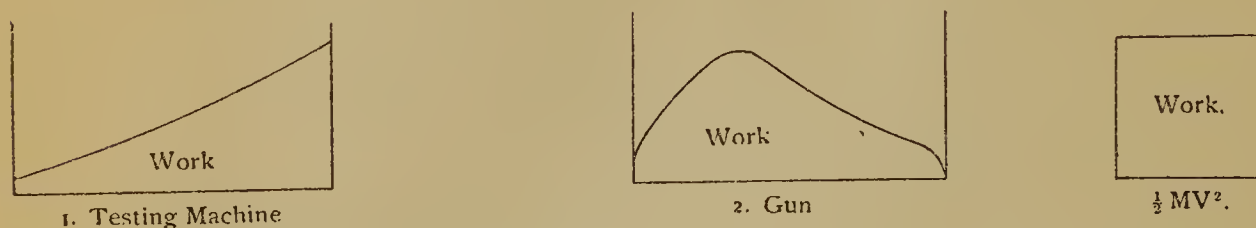
In the testing machine, when the pressure falls below the resistance, the piston comes to rest. Why does it continue to move under the action of the powder gases? Because the force is now kinetic. The energy is stored in the piston by virtue of its inertia, and is given out as required to overcome the resistance till its allotted task is finished.

The attentive reader may say this is the same case as that of work by a falling weight. It is something like it, but there is a radical difference. In one case the force begins as a maximum, as a completed force, and receives no accession during the path. It acts with one impulse. In the other case, that of powder in the gun, the force begins to act on the copper with a very low intensity (determined by the initial resistance of the copper) and receives continual accession throughout the path. In one case the force is impulsive; in the other it is varying and incessant. Moreover, in the first case the path is described in an instant; in the other probably in some fraction of a second. The first is quick compared with anything; the latter is quick compared with some things and slow compared with others. The first action develops the highest limit of copper resistance; the second is prolonged enough to allow this resistance, even if it is developed, to pass into the lower form.

To show the futility of attempting to obtain the pressure from the

work in the case we have been considering, let us construct the crusher diagrams of action (now representing work) for the testing machine and the gun once more.

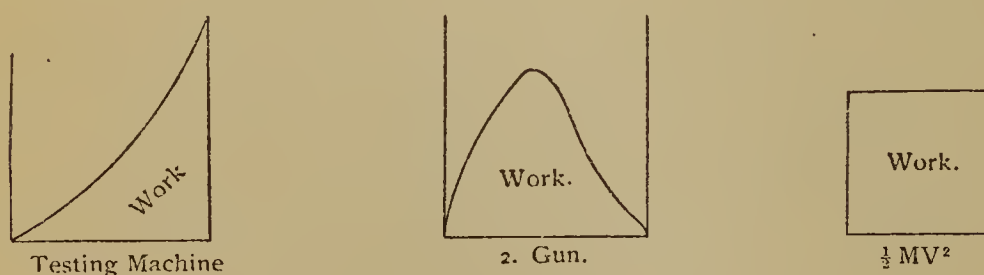
DIAGRAMS FOR CRUSHER GAUGE.



Let the ordinates represent pressures or intensities, and the abscissas paths. The area of the first diagram is the work done in the testing machine. The path being the same in the two diagrams, if we know the form of the curve in the second diagram, we can deduce the varying intensities of the force which, as ordinates, will give the same area or work. But can we consider these intensities powder pressures?

Unfortunately for the hypothesis we cannot, for if we shorten the path, as in the following diagrams for the cutter gauge, the powder

DIAGRAMS FOR THE CUTTER GAUGE.



charge and, therefore, the work, being the same, we must reckon a higher intensity for the gun diagram, although the action of the gases in the gun must have been the same.

We see, therefore, that when the record in the gun is to be interpreted as *work* there is no way of obtaining the *absolute* intensity of the force, as represented by pressure in the bore. The only safe relative measure then for the force is the square root of the work.

Our next purpose is to show that the distinction between interpreting the gun record as work and interpreting it as pressure is radical, and that it is necessary in any given case to choose between them.

By putting in the bore of the gun either a cutter or crusher gauge, or both, we cannot alter the circumstances of the powder action. If the record is one of work, the work shown by the two gauges will be the same; if it is a record of pressure, the pressure shown by the two will be the same. I propose to show that generally, if the pressures agree, the works will disagree, and *vice versa*.

My first step has been to prepare certain tables showing the relation between work, pressure and path, as deduced from the action of the testing machine for both cutter and crusher gauge. These have been prepared from the data of the Rodman tables and the corresponding curves which give the relation between pressure and path. By integration of the area corresponding to a given path (that is, the area between the curve, axis of paths, and extreme co-ordinate representing the pressure), I first constructed tables of the work corresponding to a series of paths for both instruments, then curves showing this relation, from which curves I could obtain the interpolations more readily. From these curves (see Plate IV, Fig. 3, in which they are plotted on a small scale) I took the required data.

My original data consisted of the Rodman scale of pressures for the crusher, prepared at Frankford Arsenal, and the Rodman scale of pressures for the double wedge or pointed cutter used by General Abbot.

It was my intention to include in the scope of my work the *curved cutter*, now generally used by the Ordnance Department, and I did a good deal of work in this direction before I became convinced that my data was insufficient for the purpose. The cutter was obtained from the National Armory, being part of the equipment of a new .30 calibre rifle for testing smokeless powders. The edge of the cutter was the arc of a circle 3 inches in diameter, the cutting angle being 60° and the piston $\frac{1}{30}$ square inch in cross section. I received a scale of pressures with the cutter extending from 20,000 pounds to 79,000 pounds on the square inch, corresponding to *lengths* of cuts from .498 to .806 inches. I computed the paths, that is, indentations, from a table of natural sines and reduced them to feet, the corresponding pressures being divided by 30, and found my extreme pressures 667 and 2633 pounds, and my extreme paths .00173 and .00460 feet. This left a wide gap near the origin of the curve I desired to plot.

I attempted to fill this gap, and at the same time determine the initial resistance by placing weights on the piston without shock and determining the corresponding indentations in copper. The copper used was the kind recommended by the Springfield authorities, obtained from Moffet, of New York. I got *four* satisfactory interpolations in this way, and concluded that the initial resistance was very small, probably about 10 pounds.

However, when I came to plot the curve I found the armory data gave me nearly a straight line (curving slightly the wrong way), which offered no promise of reaching the origin without a violent change of direction; instead it pointed to a large negative resistance at the origin. I therefore concluded that this scale had not been determined in the usual testing machine, and reluctantly gave up the task of going further with the matter. The following is an abridged table of the data used in plotting the unfinished curve, which will be found on Plate IV, Fig. 2. The first four items in the table are mine. The rest were computed from the Springfield scale of pressures.

Relation Between Pressure and Path. Curved Rodman Cutter $\frac{1}{30}$ " Piston. Edge Arc of 3" Circle. Most of Data from Scale of Pressures Prepared at the National Armory, April, 1891.

Length cut (inches).	Path depth of cut (feet).	Pressure (pounds).	
.028	.000005	13	These data were obtained by placing weights on the piston without shock, the cutter edge resting on copper.
.068	.00003	17	
.131	.00012	41	
.298	.00062	313	
.498	.00173	667	Armory data.
.522	.00191	800	
.546	.00209	933	
.570	.00228	1,067	
.615	.00266	1,333	
.658	.00304	1,600	
.699	.00344	1,867	
.738	.00384	2,133	
.775	.00424	2,400	
.806	.00460	2,633	

For the sake of convenience in studying the subject, I have arranged the data relating to work, pressure and path for the crusher and pointed cutter gauges into three tables. The first is arranged with reference to work, the second with reference to pressure, the third with reference to path.

A cursory examination of these tables shows (see also curves on Plate IV, Fig. 3):

1. Work being the same	{	Pressure.
		Cutter > crusher, except for very small work.
		Path.
2. Pressure being the same	{	Crusher > cutter, except for moderate and small work.
		Work.
		Crusher > cutter.
3. Path being the same	{	Path.
		Crusher > cutter, except for very small pressures.
		Work.
	{	Cutter > crusher, except for very small paths.
		Pressure.
		Cutter > crusher, except for small paths.

Relations of Work, Pressure and Path. Crusher and Cutter Gauges in Rodman Testing Machine. Arranged for Work.

Work (Foot-pounds).	Pressure (pounds).		Path (feet).	
	Crusher (cylinders).	Cutter (pointed) (discs).	Crusher (cylinders).	Cutter (discs).
0.1	550	230	.00019	.0010
0.5	699	630	.00082	.00195
1	863	965	.00146	.00260
2	1,151	1,560	.00241	.00343
3	1,370	1,940	.00319	.00399
4	1,564	2,400	.00387	.00447
5	1,716	2,740	.00448	.00486
6	1,865	3,100	.00504	.00520
8	2,103	3,660	.00605	.00580
10	2,313	4,300	.00696	.00630
12	2,514	4,830	.00779	.00674

Work (Foot-pounds).	Pressure (pounds).		Path (feet).	
	Crusher (cylinders).	Cutter (pointed) (discs).	Crusher (cylinders).	Cutter (discs).
14	2,680	5,300	.00856	.00713
16	2,845	5,780	.00929	.00748
18	2,975	6,250	.00990	.00780
20	3,115	6,700	.0106	.00865
25	3,434	8,000	.0121	.00870
27	3,545	8,640	.0127	.00895
30	3,745		.0135	
35	4,020		.0148	
40	4,320		.0160	
45	4,585		.0171	
50	4,854		.0183	
55	5,134		.0192	

Relations of Work, Pressure and Path. Crusher and Cutter Gauges Treated in Rodman Testing Machine. Arranged for Pressure.

Pressure (pounds).	Work (foot-pounds).		Path (feet).	
	Crusher (cylinders.)	Cutter (discs).	Crusher (cylinders.)	Cutter (discs).
1,000	1.3	1.05	.0017	.0027
2,000	7.0	3.20	.0056	.0040
3,000	18.1	5.75	.0101	.0051
4,000	34.7	9.00	.0147	.0061
5,000	52.6	12.80	.0186	.0069
6,000	70.5 (?)	16.80	.0216 (?)	.0076 (?)
7,000		21.00		.0082
8,000		25.00		.0087
9,000		28.10		.0091

Relations of Work, Pressure and Path. Crusher and Cutter Gauges in Rodman Testing Machine. Arranged for Path.

Path ($\frac{1}{1000}$ feet.)	Pressure (pounds).		Work (foot-pounds).	
	Crusher (on cylinders).	Cutter (on discs).	Crusher (cylinders).	Cutter (discs).
1	800	235	0.75	0.106
2	1,050	650	1.7	0.53
3	1,320	1,250	2.7	1.47
4	1,580	1,950	4.2	3.07
5	1,845	2,900	5.8	5.49
6	2,070	3,940	7.7	8.90
7	2,313	5,120	10.0	13.43
8	2,540	6,640	12.2	19.80
9	2,760	8,800	14.9	27.47
10	2,975		18.0	
12	3,400		24.5	
15	4,060		35.5	
20	5,360		59.5	

The tables and curves have involved considerable labor, but they may serve to help some student of the subject. We can show their utility by a practical case. Suppose both cutter and crusher gauges to be used in a gun, and that the path (compression) for the crusher is .0060 feet, for the cutter (indentation) .0041 feet. The corresponding pressures are 2,070 and 2,050 pounds. The corresponding works are 7.7 and 3.25 foot-pounds. In this case the record would be one of pressure since the pressures are practically equal, while the work for the crusher is more than double that for the cutter.

But suppose the path for the crusher to be .00448, while that for the cutter is .00486 feet. The corresponding pressures will be 1,716 and 2,740 pounds, while the work will be 5 foot-pounds for each. The record in such a case is a record of work since the pressures disagree.

This would make the question one of fact, to be determined by a comparison of the records of the two instruments, and when we can bring a question to this satisfactory state there is little room left for argument. We may make some effort, however, to reconcile the two views of the question which we have tried to present fairly and which we now see are incompatible in any particular case. If one is right, the other is wrong. The fact is, we know very little about the action of powder gases. Both views rest upon simple but contrary hypotheses in regard to this action—one that the powder acts so slowly that pressures and resistances are virtually in equilibrio, the other supposes this action to be quick enough to be converted into kinetic energy. In the first case no kinetic energy is developed—the record is pressure. In the second case the energy is entirely kinetic, and the record is work.

Now gunpowder covers a great range of sizes of grain. Between grains 1.5 inches in diameter and fine grained rifle powder there is an immense gap. The time of burning may be taken directly proportional to the diameter of the grains, perhaps giving a ratio of 100 : 1 in the times of action for the two cases. Time of action determines whether the powder gases will act as a pressure or kinetically. It is possible, therefore, that one view is applicable to the coarse powder and the other to the fine.

The only suggestion of value I have to offer as an outcome of the study given to the subject is this: *by using two gauges presenting*

different resistances, the question in regard to the interpretation of the record becomes one of fact to be determined by a comparison of the two records.

All then that is required to solve the question generally is certain data of this nature, data which I unfortunately lack.

For slow-burning powders I have no doubt that the Rodman principle is reliable. This was the case it was designed to meet. I have too much admiration for this original thinker, as well as respect for the accomplished corps of officers who have followed in his footsteps, to lightly criticise his work, even if I thought there was a chance to do so, but I wish to state my belief that the Rodman principle is perfectly reliable for the cases to which he intended it to be applied.

But I do not believe that the Rodman gauge can be used to determine the pressures of fine-grained quick powders in small arms. I regret that I cannot support this by experimental data as I had hoped to do in time for this paper.

Whether or not the record in such a case is a reliable one of work would depend upon whether or not the *whole* energy of the powder acts kinetically.

It is hard to conceive that there should be an exact point at which the record ceases to be a pressure and becomes work, in fact, impossible.

It would seem from this that there may be such a thing as a mixed action.

We have always, however, our criterion—the agreement or disagreement of the two gauges. If they agree upon pressure, the record is pressure. If they agree upon work, the record is work. If they agree in neither, then there has been a mixed action, and a comparison gives either one or the other predominance. It is evident, I think, that a valuable study of the particular powder may be made in this way, and a good idea may be formed of its mode of action in the gun.

Professor Bartlett suggested in his original criticism of General Rodman's scheme the use of a series of measured initial resistances of different intensities as a substitute for the Rodman gauge. The English experimenters in using a cylinder already compressed virtually applied this principle. The compression not being increased, they assumed very properly that the pressure did not exceed the

figure corresponding to the first compression. But this was a typical case of slow-acting powder giving a record of pressure.

Does this prearranged initial resistance, approximating the final resistance developed by the powder action, present any special advantage in gauging quick powders? It may be said, in its favor, that the force cannot act kinetically unless it can overcome the initial resistance, but it can also be said *per contra* that if it *does* act kinetically it *will* overcome the resistance, as illustrated by my experiments in the foot-pounds machine. It may be remembered that I took copper cylinders very highly compressed and dropped the weight on them from very minute heights, in every case getting a record of work.

It does not seem to me, therefore, that this plan entirely overcomes the difficulty of obtaining an absolute figure for the pressure, when the record made in the ordinary way would be an unequivocal record of work. It simply shortens the path and shows a corresponding high intensity of action, when a longer path, as in the ordinary case, would show a less intensity. The difficulty would be this: as the force is certain to act, the higher the initial resistance is set the higher the pressure that would be credited to the powder.

In mixed actions, however, this plan might serve a good purpose in determining the mode in which the powder would act. The piston would have no chance to acquire living force by moving over a comparatively unguarded path. I think, therefore, that in the general case of quick powders an initial resistance would be useful in converting a doubtful record into a record of pressure. However, the conclusions in such a case should be checked by using two different instruments.

It is possible that no explosive used in fire arms is capable of writing a record of work which will agree in two such different instruments as the cutter and crusher gauges. This we cannot settle positively, but think that the fine grained smokeless powders proposed for small bore rifles may do so. In dealing with these agents we are really dealing with high explosives, although under a new form possessing new properties. The condition required for explosion is analogous to the condition for detonation—pressure for one and shock for the other. Smokeless powders are feeble or strong in proportion to the initial pressure which causes explosion. In gunpowder the burning is progressive, and the velocity of combustion

is independent of the pressure. In smokeless powder the burning is, or should be, progressive, but the velocity of combustion is directly dependent on the pressure. Between conditions which will not cause it to burn at all, and conditions which will cause it to explode violently, the step is very short. Finally it differs from gunpowder in this: the gunpowder reaction is external between molecules, the smokeless powder reaction is internal between atoms in the same molecule. These differences would seem to show that caution should be exercised in applying the same tests to the two explosives. In suggesting the use of the two gauges, we think we have indicated a method of working which will throw light upon the action of the newer agent.

PLATE I.

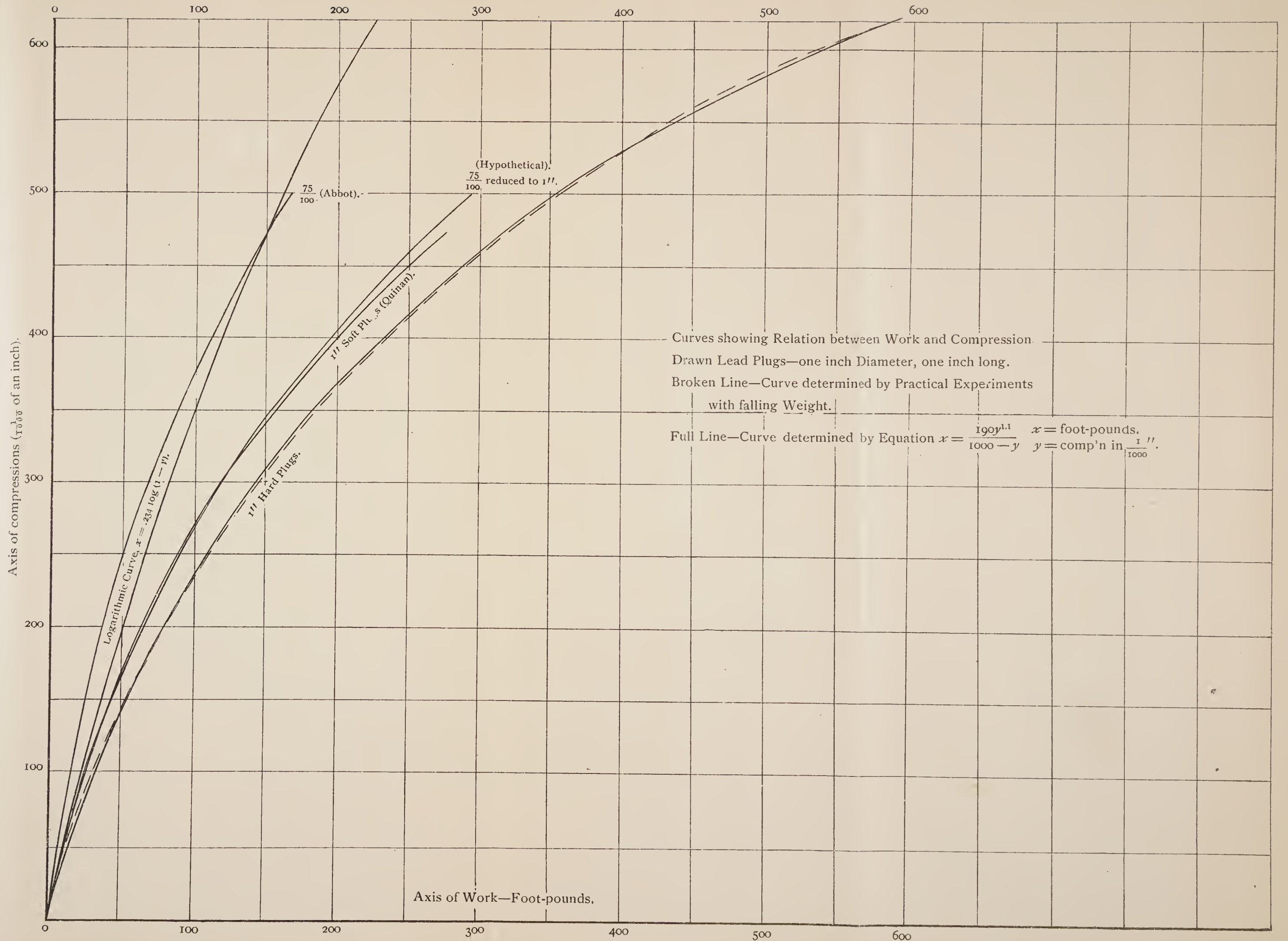


PLATE II.

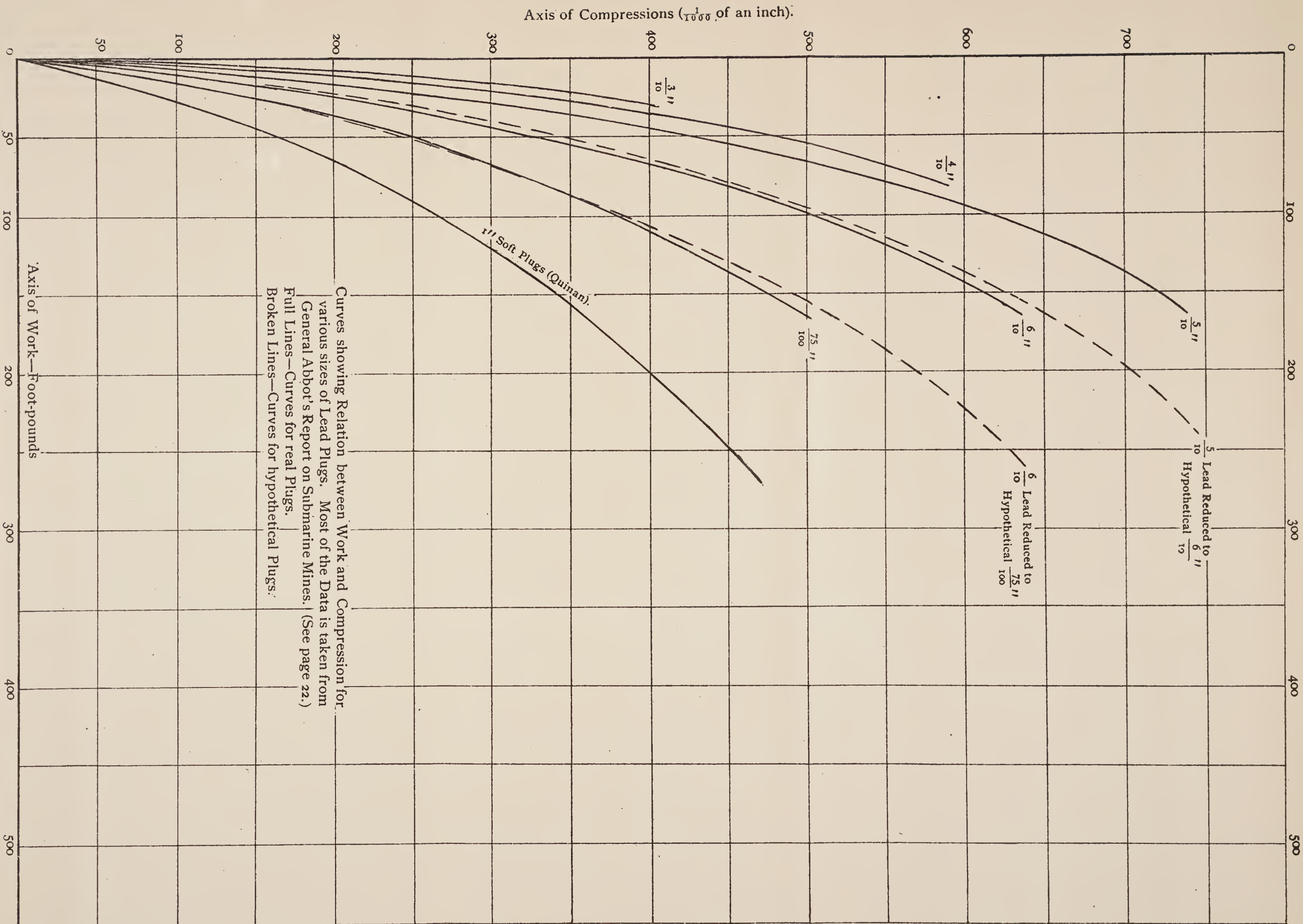


PLATE III.

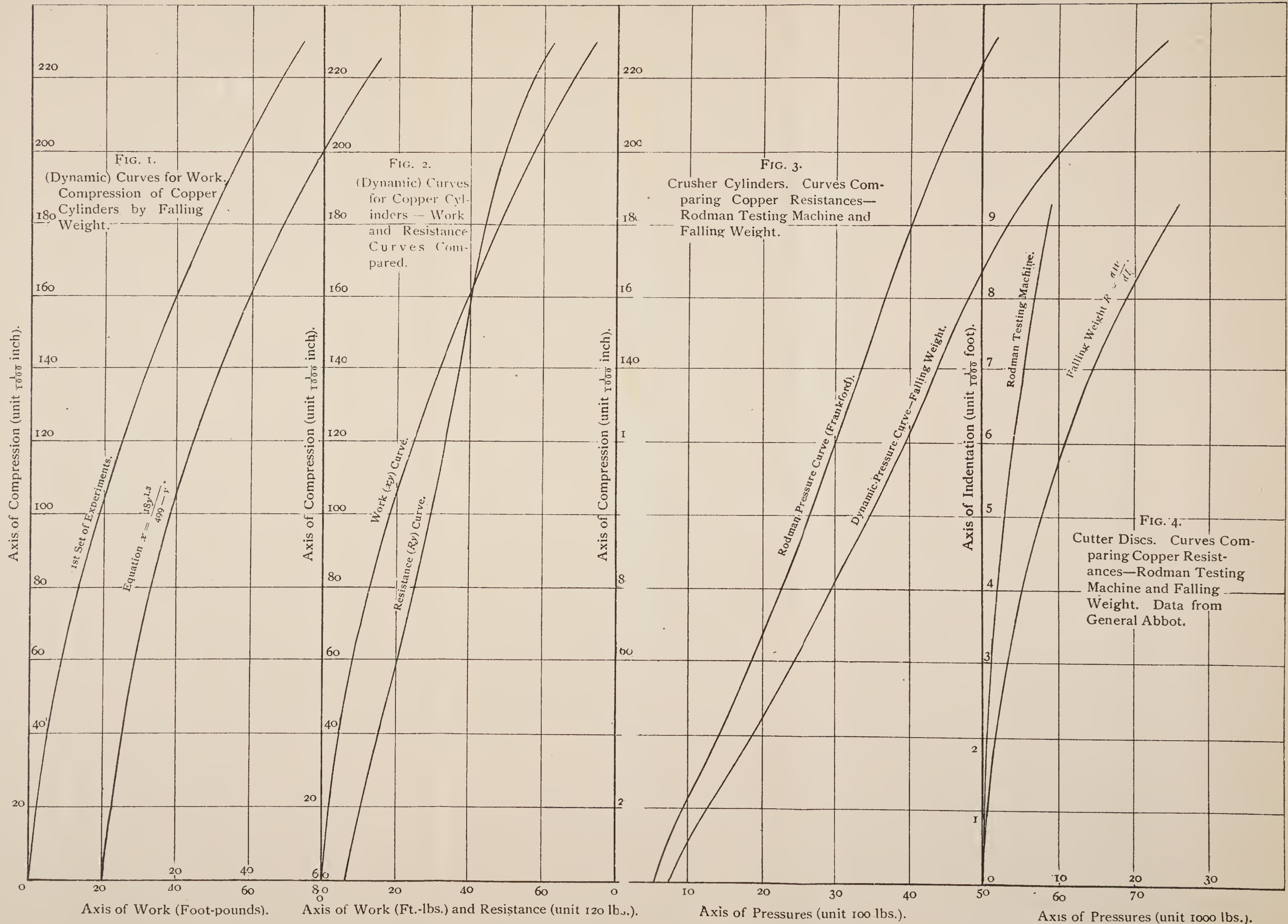


PLATE IV.

FIG. 1.

Dynamic Curves for Pointed Cutter.
Work and Resistance Curves.
Data from General Abbot.

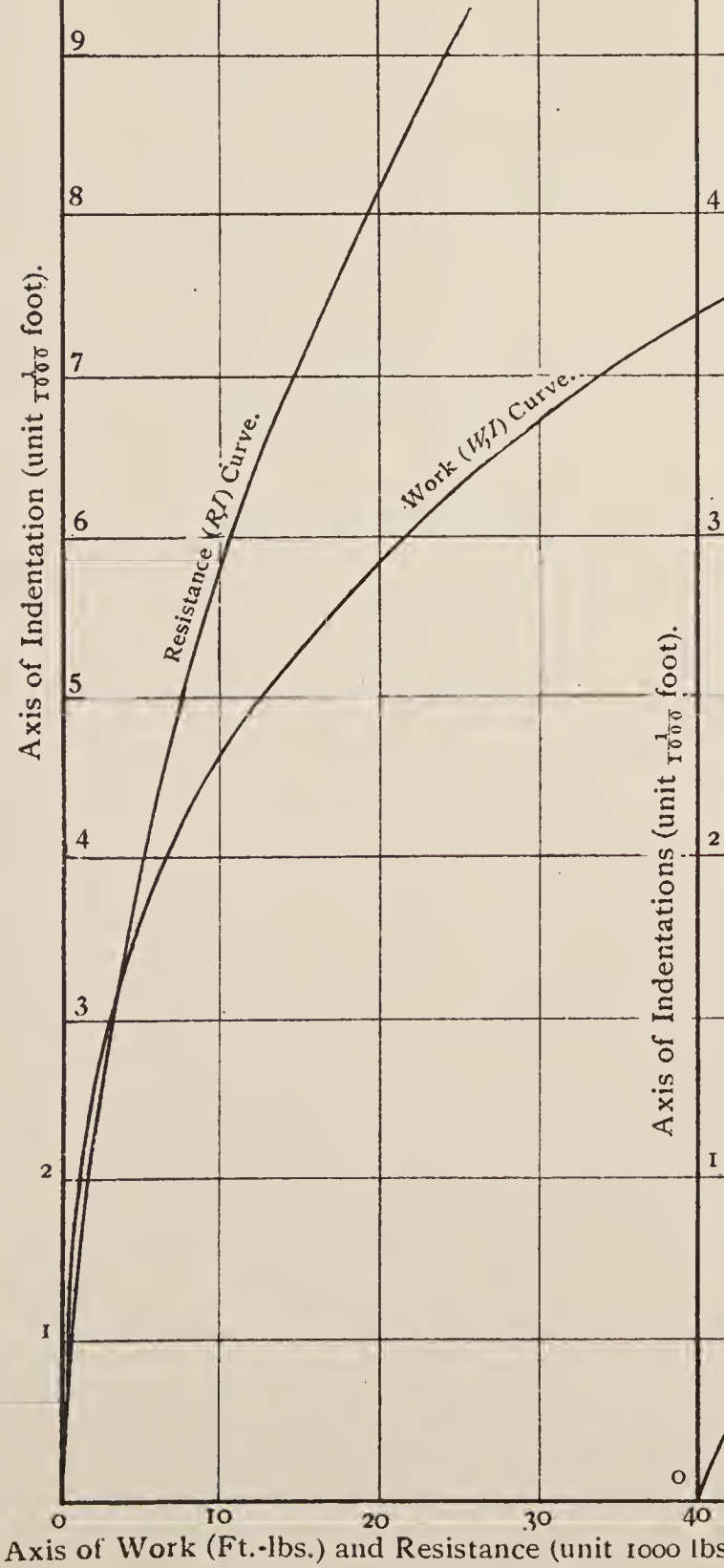


FIG. 2.

Curve for Springfield
Curved Cutter.

Axis of Indentations (unit 1000 foot).

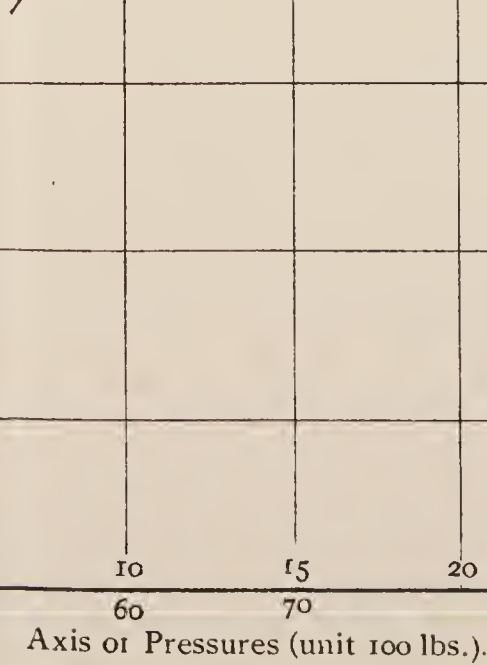
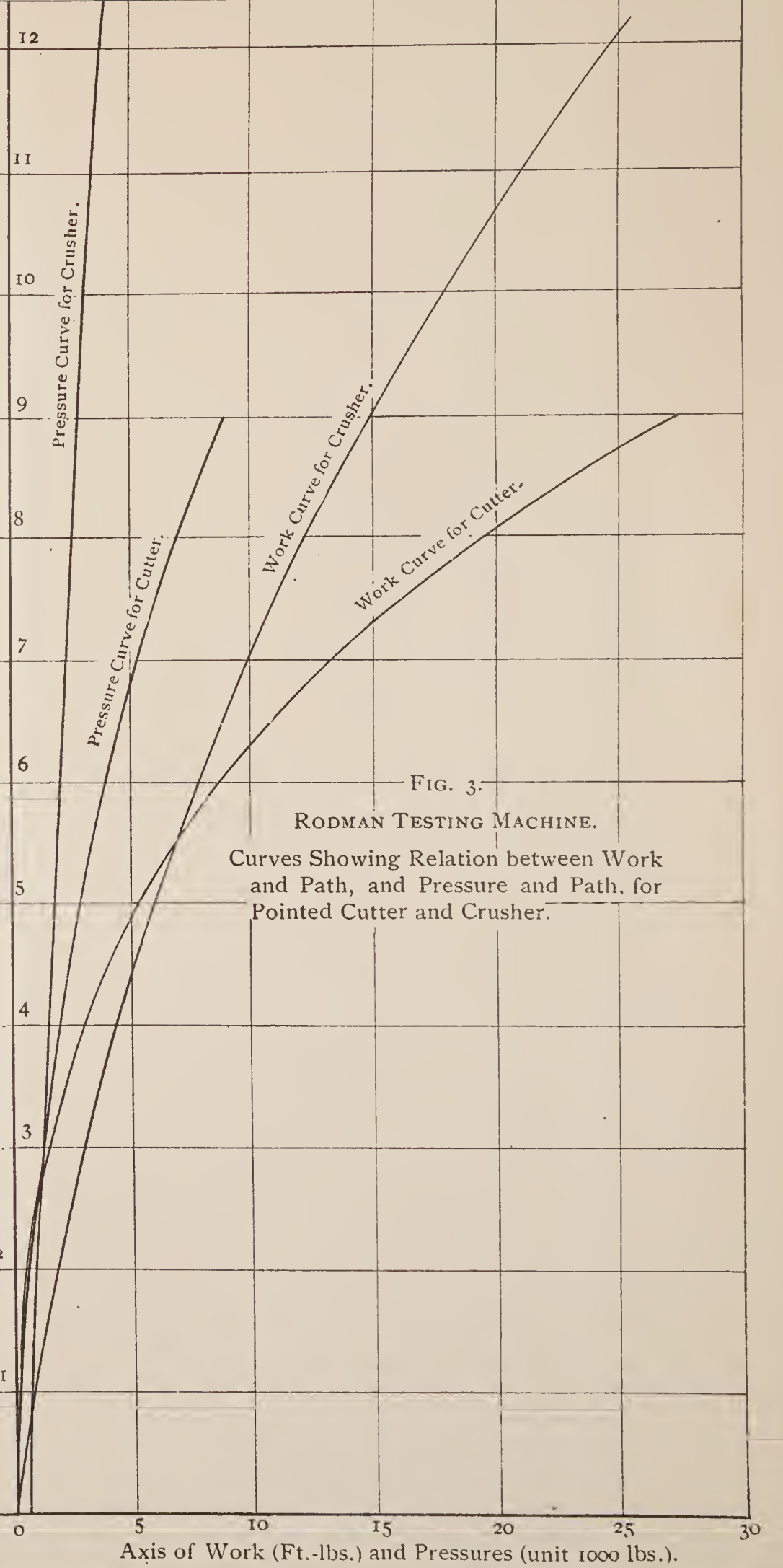


FIG. 3.

RODMAN TESTING MACHINE.
Curves Showing Relation between Work
and Path, and Pressure and Path, for
Pointed Cutter and Crusher.

Axis of Paths (unit 1000 foot).



TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL, 1884.

TRANSACTIONS.

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XVIII.

VOLUME II.—APRIL, 1885.

A TALK ABOUT EXPLOSIVES.

By WM. R. QUINAN, Mem. Tech. Soc.

Read April 3, 1885.

The use of gunpowder in Europe can be traced only to the middle or early part of the 14th century. It is not likely that the crude experiments of the German monk, Berthold Schwartz, had much influence in introducing it into European warfare. The better theory seems to be that a knowledge of it was obtained from the Saracens. The invention probably had its origin in central Asia, where saltpetre occurs as an efflorescence on the soil, and where the campfires of the prehistoric nomad must have frequently sputtered from the deflagration of the nitre in contact with the heated embers. The Chinese appropriated the discovery at a very early period, and fireworks were common in that country when Europe was peopled by primitive savages. There are records which seem to show that when Alexander invaded India in 327 B. C., he encountered tribes that used something equivalent to the modern rocket. In the invasion of China by Gengis Khan in A. D. 1219, similar fire machines were used. Wars and migrations of tribes disseminated a knowledge of gunpowder over Asia and northern Africa, and in the hands of the Saracens the art seems to have advanced to its use as a projectile agent.

We find the Moors using it in this way in Spain in 1312, and soon afterwards guns made their appearance upon the battlefields of Europe.

Whether this rough historical sketch be substantially correct or not, a knowledge of the composition of gunpowder and of its manufacture in a crude way, seems to have existed from time immemorial throughout the greater part of central and southern Asia. In this primitive method of manufacture, the incorporation of the ingredients is effected in a wooden mortar, the pestle being often worked by a treadle. This method is still in use in India among the hill tribes, and in Afghanistan, where the work is usually done by the women. The moist mass taken from the mortars, is grained by being rubbed through sieves of catgut. The grains dried in the sun, are used without further preparation. In Col. Anderson's account of the Bengal Powder Mills, he gives some tests of a superior Sekh Powder obtained from one of the native princes—2 ounces of which in the 8-inch mortar gave a range of 53 yards, while the Bengal powder gave 94. The appearance of the native powder is thus described—"grains mixed, round as if cast, not very hard, not much dust, color bluish-black." An analysis showed normal or nearly normal proportions of the ingredients. Its only inferiority seemed to lie in the fact that the saltpetre was not well refined.

The same author tells of a clever device for projecting a small shell without gun or mortar which one of the Sekh sirdars exhibited to a British officer. The sirdar excavated a hole in the ground at an angle of about 45° , slightly contracted at the bottom so as to form a small chamber. The chamber was next reinforced by driving in several tent pins till their heads were flush with the bottom. A piece of quick match being laid to the mouth of the hole, a small charge of powder was introduced, and then the shell placed in with fusee lighted. Upon lighting the quick match, the shell was projected about 300 yards and exploded in falling to the ground. The excavation was very little injured by firing two rounds.

This story reminds one of the giant mortars of the island of Malta, made by excavating holes in the solid rock; and also of the device in fortification called a *stone fougasse*, a sort of impro-

vised underground mortar for throwing a shower of small stones, which was once in fashion for the defense of strong places.

Requirements of Gunnery.—Gunpowder owes its efficiency as an explosive, to certain chemical relations existing between its ingredients, but a perfect incorporation of these ingredients is essential to the full development of its force. It is important to observe that the evolution of its gases, is the result of a veritable combustion, and is therefore progressive. In the high explosives, on the contrary, the decomposition is supposed to be propagated by a vibration throughout the mass, and is sensibly instantaneous. The fact that gunpowder gives off its gases at a certain rate is the most important element in its use as a projectile agent; indeed, it is this property which suits it to the hand of the artillerist. The velocity of combustion is the rate at which solid powder burns and is defined to be the space passed over by the burning surface in a second of time, the space being measured perpendicular to the surface. This velocity is affected by several circumstances. It increases with the purity, dryness, and thorough incorporation of the ingredients, and diminishes with the density. That is, other things being equal, a carefully made powder burns most rapidly, and a light powder burns more rapidly than a heavy one. In the explosion of a charge, there is another velocity to be considered—that of inflammation, or the spread of the flame from one grain to another. This must not be confounded with combustion—the burning of the grains from surface to centre. It has been found by experiment that good gunpowder burns at the rate of about one half inch per second, while the velocity of inflammation, though it varies greatly with circumstances, and is much reduced by the presence of dust, may be taken between 25 and 100 feet in the explosion of a charge of grained powder. We may therefore suppose for our present purpose that the grains are all ignited at the same instant. It is evident that the evolution of the gas of a charge can be regulated to some extent by employing grains of a certain size. The smaller the grain the sooner the charge is burnt, and the quicker the evolution of gas. With small or light projectiles, the gases may be developed suddenly, and small grain powders are admissible. In large guns where the projectile

has great weight, it becomes necessary to the safety of the gun, to develop the inertia of the shot slowly. Experiment has proved that the pressure on the bore of a gun is by no means equal at all points of the bore, but is greatest near the seat of the charge. The disproportion is the greater, the smaller the grains. The aim in heavy guns is to lighten the initial pressures and increase the subsequent ones, so as to bring about something like an equality. When a charge is lighted in the bore, experiments have proved that the pressure mounts almost instantly to a little below the maximum, then more slowly to the maximum, at which moment the shot has moved so far that the pressure of the gas, which is still increasing, is balanced by the increase of room left by the moving shot. From that moment the life of the gun is safe. It is evident that the conditions aimed at cannot be fulfilled by ordinary grains of powder, no matter how large, because from the relations between concentric spheres of equal thickness the amount of gas evolved in the first instants of burning will be too large, tending to excessive pressure, and that in the last instants will be too small, and will fail in accelerating the shot.

Gen. Rodman, of our Ordnance Department, was the first to clearly comprehend this difficulty, and to attempt a remedy. His solution was to compel the powder to burn on an increasing instead of a diminishing surface. He gave his powder the form of large cakes, perforated with numerous holes. His experiments with this powder showed a marked diminution of maximum pressure with increased effect on the projectile. Experiments since Rodman's death have failed to confirm his results. Accidents have occurred, possibly from the wedging of the broken cakes in the bore.

Lieutenant Totten, of the 4th Artillery, is the inventor of another method of meeting the difficulty. He calls his a "compensating powder." He proposes a spherical grain of gunpowder inclosing a small core of gun cotton. The projectile is started by the gunpowder, but is accelerated after passing the danger point by the quicker burning gun cotton. His patent covers other combinations as well, the general idea being to combine a slow and quick burning explosive, so as to make them operate at different periods in the explosion of the charge.

Composition and Manufacture.—In its best known form, gunpowder consists of potassium nitrate, sulphur, and charcoal. This composition is the one still used in military and sporting powders. In blasting powder the potash salt has been very generally superseded by sodium nitrate. For blasting purposes the latter is but little inferior to saltpetre, while its cost is much less. The slightly deliquescent nature of the soda salt has been counteracted by a high degree of glazing and the use of metallic cases for packing.

The tendency of late years in the manufacture of blasting powder, is to also lessen the cost, by doing away with the older elaborate methods of grinding and incorporating the ingredients. An intimate mixture is obtained by dissolving the nitrate in the smallest possible quantity of boiling water and stirring the other ingredients, previously ground and mixed, into the solution. To prevent the nitrate from crystallizing too coarsely, the mixture is vigorously stirred during the evaporation of the water. Sometimes the mixture is ground a short time in the wheel-mill, and sometimes granulated directly from the boiling vat by being rubbed while damp and cohesive through coarse sieves. In most mills it falls upon a wide canvas belt, which transports it to the drying house.

This powder is deficient in density and cohesion, and unless glazed, has poor keeping qualities. The incorporation is very imperfect, the crystals of nitrate being visible to the naked eye. It works fairly well as a blasting agent, though it is very slow in spite of its lightness.

Sometimes the grains are toughened, and the explosive qualities of the powder injured by the addition of a small percentage of sugar to the other ingredients. This method of manufacture is very old. It was used more or less in Europe during the seventeenth and eighteenth centuries. Nevertheless, with various minor modifications, it has been the subject of a half dozen United States patents.

On this Coast this method has been identified more or less with Mr. Orlando B Hardy, of Akron, Ohio, who took out a patent for a new blasting powder in 1879. The novelty consisted in adding to the ordinary ingredients salt, sugar and paraffine—

whereby he obtained a powder "fully equal in dynamic effect to 'Giant' or 'Hercules,'" and which had also the property of being "non-explosive in the open air."

Mr. Hardy established a mill at Vallejo, where he turned out at first probably the worst specimen of blasting powder which has ever been offered to the public. These works were blown up in 1882, after he had left them, but were rebuilt at Sobrante. They now turn out a very handsomely glazed powder called "Granite." Hardy was employed by the Vulcan Powder Company to build and take charge of works at Stege. The powder made here was a crude, unglazed product, and was largely used in contracts with the Southern and Central Pacific railroads, under the name of "Vulcan B. B." or "Bank Blasting." As its name implies, it was made specially for the hydraulic mines, in which it found some application. The works at Stege were blown up and rebuilt in 1882. In 1883 the powder was changed by adding a small proportion of nitro-glycerin, into a detonating explosive, under the name of "Ajax." This powder was largely used for a short time in a contract for extending beyond Redding the Oregon branch of the Central Pacific. The powder contract, so far as it concerned the Vulcan company, was ruptured suddenly by the transference of Mr. Hardy's allegiance to the Giant company. Upon the grounds of the latter, near Berkeley, works were erected similar to those at Stege. The only change of importance was the use of hot air instead of steam for the dry-house. These works have a capacity of 20 or 25,000 pounds of powder per day.

The "Ajax" powder was changed by substituting ordinary coal for charcoal, and took the name which it still keeps of "Judson Improved."

The most notable departure, perhaps, from the ordinary methods of manufacturing gunpowder, is that of Col. Bernhard Wiener, of the Russian Artillery. He takes the dry meal from the mixing tubs or barrels, and subjects it to the action of a press heated to about 250° Fahrenheit. This causes the sulphur to melt and pervade the mass. The product is a light but very firm powder. It is said to stand water well. The process is quicker and cheaper than the old, but little is known so far

of the general qualities of the powder. Col. Wiener took out his U. S. patent in March, 1874. Some specimens of his powder were sent for by the authorities of the Artillery School at Fort Monroe, but I have not heard whether any tests were made.

The situation of this Coast during the War of the Rebellion, when all the Eastern mills were working day and night upon government contracts, and the dearth of blasting powder for the hydraulic mines and railroads ran the price up some three or four times the normal, was a powerful incentive to inventors of rough-and-ready powders. Mr. Egbert Judson once told the writer of a venture of his at this time. He went off into the sand-hills of San Francisco and erected some shanties, from which, inside of a week, he was shipping powder to the mines. The carbonaceous element was principally sawdust, a part of the nitrate being replaced by potassium chlorate. To give a black color, sulphate of iron was added in small quantity. This formed an ink with the tannic acid in the sawdust. The powder was made by dissolving the nitrate and chlorate in hot water and stirring in the other ingredients. Mr. Judson says he made money until the better made Eastern article began to return to the market at lower prices, when he demolished his shanties and gave up the business.

Gunpowder Modifications.—The progress of the arts has introduced more or less extensively a great number of inventions intended to supersede gunpowder as a blasting agent. In the composition of these explosives, inventors have been guided very generally by the principle of the older explosive. Most of the attempts to invent something new have consisted in obvious modifications, made by substituting equivalent elements for those of gunpowder. Under the head of substitutes for charcoal, we find tannin, coal, peat, sawdust, bark, paraffine, starch, sugar, etc. All of these substances are deficient in chemical energy as compared with charcoal. The effect of using them with a nitrate as the oxidizing agent, notwithstanding the claims of the inventors, is to weaken the powder by making it slow and sluggish. For certain kinds of work these compositions may do very well, but for general purposes they are inferior to the old explosive.

Perhaps a judicious use might be made of them in some modified form of gunpowder for heavy guns.

Under the second head of oxidizing agents we find the nitrates, chlorates, etc. There appears to be a great choice of these substances, but when we examine the subject closely we find that the choice is very limited.

The following is a table of some of the nitrates, showing the percentage of oxygen, etc.:

NAME.	SYMBOL.	Molecular Weight.	Percentage of Oxygen.	Percentage of Gaseous Constituents.	REMARKS.
Urea Nitrate.....	$\text{COH}_5\text{N}_2(\text{NO}_3)$	123	52.0	100.	Stable—not deliquescent.
Ammonium Nitrate.	NH_4NO_3	80	60.0	100.	Deliquescent.
Magnesium Nitrate.	$\text{Mg}(\text{NO}_3)_2$	148	64.9	83.8	“
Calcium Nitrate...	$\text{Ca}(\text{NO}_3)_2$	164	58.5	75.6	“
Sodium Nitrate	NaNO_3	85	56.5	73.0	Hygroscopic.
Ferrous Nitrate ...	$\text{Fe}(\text{NO}_3)_2$	180	53.3	68.9	Unstable.
Potassium Nitrate..	KNO_3	101.1	47.5	61.3	Stable soluble.
Strontium Nitrate..	$\text{Sr}(\text{NO}_3)_2$	211.5	45.4	58.6	Sparingly “
Barium Nitrate... ..	$\text{Ba}(\text{NO}_3)_2$	261	36.8	47.5	“ “
Lead Nitrate	$\text{Pb}(\text{NO}_3)_2$	331	29.0	37.5	“ “

This table shows the nitrates arranged according to the percentage of gaseous constituents. The percentage of oxygen is also shown in one of the columns. All of this oxygen is not available however for outside combination. For instance, though the urea nitrate is a genuine nitrate, it is not an oxidizing agent at all, as every atom of oxygen in decomposition is required to oxidize the other constituents, and even then there is not enough. The ammonium nitrate is an oxidizing agent, but a feeble one, as it contains only one atom of oxygen for outside combination. The other nitrates are genuine oxidizing agents, but most of them are unfit for powder. The nitrates of lime and magnesia are so deliquescent that they are worthless for explosive purposes. The ferrous nitrate is unstable—that is, liable to spontaneous decomposition. This leaves five available ones—the nitrates of soda,

potash, strontia, baryta, and lead. We are already familiar with the first two. The others are feeble, partly from deficiency of oxygen and partly for another reason. Judging from this table the sodium nitrate should be superior to potassium nitrate, but the latter is known to make a stronger gunpowder in spite of the greater amount of oxygen carried by its rival. When a gunpowder is fired, various solids are formed, which are salts of potassium, or sodium, or barium, etc., accordingly as the nitrate used in the powder is a potassium, sodium or barium nitrate. The formation of these salts develops different amounts of heat, depending upon the nature of the base. As the heat is one of the elements of strength, we see why the gas-forming capacity of the nitrate, taken alone, does not measure the strength of the corresponding gunpowder.

In addition to the nitrates, there are a number of other substances which have been called upon by inventors to play the part of oxidizing agents. The following is a list of certain substances:

NAME.	SYMBOL.	Molecular Weight.	Percentage of Oxygen.	REMARKS.
Hydrogen Peroxide.....	H ₂ O ₂	34.	94.0	Unstable.
Manganese Dioxide.....	MnO ₂	87.	37.0	
Zinc Oxide.....	ZnO	81.	19.8	
Lead Peroxide.....	PbO ₂	239.	13.4	
Mercury Oxide.....	HgO	216.	7.4	
Potassium Chlorate.....	KClO ₃	122.6	39.1	
Potassium Perchlorate...	KClO ₄	138.6	46.2	Very costly.
Potassium Permanganate	K ₂ Mn ₂ O ₅	268.2	29.8	Unstable.
Potassium Bichromate....	K ₂ Cr ₂ O ₇	294.6	38.0	

Hydrogen peroxide, or oxygenated water as it is called sometimes, is a very interesting substance and a powerful oxidizing agent; but it is too unstable for powder. Moreover, it is a liquid which so far has only been prepared as a solution in water. It contains, as shown by the table, 94 per cent. of oxygen, but only half of this is available for outside combination. Certain of the

metallic oxides are given in the table, because they have been proposed as powder ingredients by different inventors. A glance at the table shows that most of them are of no account. In the higher oxides, as a rule, only a part of the oxygen is readily separable. Some of the lower oxides attract carbonic acid from the air, and are spontaneously converted into carbonates. The manganates and permanganates are powerful agents, but are too unstable, being decomposed by contact with organic matter.

Potassium bichromate has been used by various inventors. It is not very energetic, and is commonly used with other and stronger agents.

Potassium perchlorate is a very interesting substance. It is exceedingly energetic, and at the same time stable. It has many properties to recommend it to inventors, but at present its preparation is too costly to bring it into the field.

Potassium chlorate is the only substance in this table which has come into general use as a powder material. By comparing the table with that of the nitrates, it will be seen that the chlorate furnishes less oxygen than either the nitrate of soda or potash. It is, however, a much more energetic agent than the nitrates. This can be explained in this way. It gives up its oxygen more readily, because it is susceptible of an independent decomposition with *evolution* of heat, thus:



If we try the nitrate in the same way, we find that the decomposition takes place in opposition to the affinities of the K and O with an *absorption* of heat, thus:



Practically we can get only a partial decomposition unless we raise it to a very high temperature.

The introduction of potassium chlorate into the arts was attended with so many accidents that it merits an extended notice. It was first made known to the world in 1785 by the celebrated French chemist, Berthollet, who named it "oxygenized muriate of potash," which was afterwards shortened to oxy-muriate of potash. When, in 1809, Sir Humphrey Davy proved

that chlorine contained no oxygen, the name was changed to chlorate of potash. The older chemists indulged in extravagant flights of imagination in describing the qualities of the new compound. Fourcroy, in his chemistry, says "it appears to include the elements of thunder in its particles," and that "Nature seems to have concentrated all her powers of detonation, fulmination and inflammation in this terrible compound." At the present day, this language seems very much strained in view of the later discoveries of the fulminates, nitro-glycerin, and other high explosives. However, the lives of the two first workmen employed by Berthollet in manufacturing gunpowder from chlorate of potash were sacrificed in the experiment. The trituration of the chlorate with charcoal and sulphur caused a violent explosion, which killed the men and destroyed the building. This was in 1788. The incorporation of these ingredients is a very dangerous operation, but it has been successfully accomplished since, by more careful experimenters, who managed it by keeping the composition wet. Several French chemists prepared such powders, and found by experiment that they had about twice the strength of ordinary gunpowder. M. Cossigny made the mixture by dissolving the chlorate in water and stirring in the other ingredients. His proportions were 75 chlorate, $12\frac{1}{2}$ sulphur, and $12\frac{1}{2}$ charcoal. He also experimented with mixtures of chlorate and nitrate in different proportions. Several attempts were made under Bonaparte to make practical use of these powders, and it is said that in one of his campaigns they were actually used. It was soon found that the injury to the gun, both from the violent nature of the explosive and corrosive action on the metal, more than counterbalanced the superiority in strength.

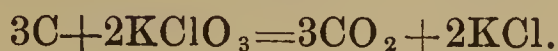
There exists among mining men a great prejudice against potassium chlorate mixtures, and this is not to be wondered at when we consider the great number of accidents which have resulted from handling it. Mixed with organic matter of almost any kind, and suddenly heated or violently struck, it will yield an explosion which is local or complete, depending upon the nature of the mixture. In contact with certain substances, it is very sensitive to friction. Grinding it has led to numerous accidents in past times, owing to organic impurities in it, or allowed

to get into it, in the mill. It is used in the arts as a source of oxygen gas, for which purpose it is mixed with manganese dioxide and heated in a retort. Adulteration of the oxide with coal, by ignorant or unscrupulous dealers, gave rise to numerous explosions. Mixed with sulphur or certain sulphides, explosion is readily caused by a blow or friction, but it is usually local unless in the presence of charcoal or carbonaceous matter, when it is apt to be violent. Mixed with sugar or the cyanides, or some of the nitro-substitution compounds, it is inflamed by a drop of sulphuric acid. The latter acid produces by its action on the chlorate alone an explosive gas. These facts and the widely varying conditions which seemed to cause accidents with it, united in giving chlorate of potash a name for instability which it does not deserve. It is simply a substance with a great range of chemical susceptibilities, which must be carefully studied by the inventor who attempts to use it in compounding powders. Undoubtedly many mixtures have been put upon the market which were intrinsically dangerous, but powders can be made from it, by consulting its chemical relations, which are reasonably safe. In a state of great purity, it is now an article of an extensive commerce. No accidents now-a-days happen with it, which can be alleged to be "spontaneous" or "atmospheric."

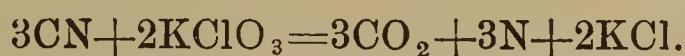
Chemistry has disclosed a great many substances which may be used in compounding explosives. We have already mentioned some capable of playing the part of oxidizing agents. Among the most interesting of the opposite nature that is capable of replacing charcoal, is carbon bisulphide— CS_2 . This is a transparent liquid, quite volatile, and having in its ordinary state of purity a repulsive odor. Mixed with potassium chlorate, it is said to form a powerful detonating explosive, but which has no practical value on account of the volatile character of one of the ingredients. When the bi-sulphide is heated with zinc and sulphuric acid, it takes up two atoms of hydrogen, forming a very interesting white solid substance having the formula CH_2S . I think it likely that this would be found an energetic agent in explosive mixtures. No experiments have been made with it.

Knowing the general principles of chemistry it is easy to

theorize on the effects of a new agent. To illustrate the course of reasoning by which an inventor arrives at a new combination, we will begin with one of the simplest reactions with potassium chlorate, viz:



Nitrogen is a substance having feeble affinities for other elements. Its presence is almost a characteristic of explosives. We can improve the reaction therefore in this way:



But CN is cyanogen, a gas. We try again. Hydrogen combines with oxygen with great avidity, producing great heat. Our equation becomes:



Here (HCN) we have another gas, a virulent poison, the concentrated aqueous solution of which is the ordinary prussic acid. But we can substitute another element for hydrogen, such as potassium, giving us potassium cyanide. This makes with the chlorate, an efficient explosive, but the cyanide is deliquescent, and the powder soon spoils. Most of the simple cyanides have the same defect—the soluble ones are poisonous. The cheapest and most stable of these compounds is the double cyanide of potassium and iron; or, as it is usually called, the ferro-cyanide or yellow prussiate of potash. This is not poisonous, and is not deliquescent. The reaction may be represented as follows:



This composition is known in the arts as “German” or “white” gunpowder. It is much stronger than ordinary powder but too costly to be very serviceable in mining. To cheapen it and to make it less sensitive to friction, sawdust is sometimes mixed with it. In some compositions sugar is used instead of sawdust. It can be exploded by a drop of sulphuric acid. A blasting powder made by mixing potassium nitrate, charcoal and the ferrocyanide, called haloxylin, has found some application in Germany.

Explosion.—Explosion is a term used in ordinary conversation to designate phenomena which are totally dissimilar except in outward and visible manifestation. Thus water is said to explode when by sudden conversion into steam it bursts a boiler. Technically, explosion is a chemical reaction which forms suddenly a body of heated gas. Explosions take various forms. The body which explodes may be a mixture of gases, as hydrogen and oxygen, which unite with great energy under certain conditions to form the vapor of water. In this case, the only expansion is from the great heat produced, as under the same temperature and pressure the vapor formed would occupy only two-thirds of the volume of the mixed constituents before explosion. Usually the exploding body is a liquid or solid which is transformed wholly or partly into gas. The gases produced by explosion are generally compound gases formed by the union of certain elements contained in the exploding body; but sometimes the case is reversed and the gases are simple elements formed by the disunion of two or more elements which were united in the explosive. This case is illustrated by the explosion of nitrogen chloride, which consists in the sudden dissociation of its elements. In gunpowder also the nitrogen of the nitrate is set free in the explosion. The gases most characteristic of explosion are the oxides of carbon, the vapor of water and free nitrogen.

Construction of Explosives.—Generally speaking the structure of an explosive exhibits two elements: oxygen on the one hand and some substance or substances having a strong affinity for oxygen on the other. In regard to composition, the most general division is into two classes: 1st, Explosive mixtures. 2d, Explosive compounds. Explosive mixtures are built up by assembling an oxidizing agent with some substance or substances having a strong affinity for oxygen and capable of forming gas by union with it. In an explosive mixture there is no union between the elements beyond an intimate mechanical one. In practice the products of explosion are both solids and gases, though it is possible to make explosive mixtures having only gaseous products.

An explosive compound is a true chemical compound, which is an explosive within itself. Nitro-glycerin, mercury fulminate and gun-cotton, are examples. The products of explosion are generally gaseous, though there are numerous exceptions as in the case of the metallic fulminates, picrates, etc. An explosive compound may be used in mixture with substances which are inexplosive in themselves or may be mixed with other explosives. To such mixtures the term explosive compounds is very generally applied though not with strictness. An explosive mixture, however, is one in which no substance enters which is capable of explosion in itself.

Explosives can be divided practically into the same two classes on another basis. Those which explode by combustion or burning, belong to the first class. Those which can be exploded by detonation, to the second class. The first class includes explosive mixtures or fire-explosives—the second class, explosive compounds and their derivatives, or detonating explosives. In the first class, explosion is caused by a progressive burning of the mass—in the second by an exploding impulse which is transmitted almost instantaneously throughout the mass. The distinction between the two forms of explosion is one of time. When we compare typical examples of the two classes—as gun-powder and nitro-glycerin, there appears to be a radical difference, but when we examine a variety of explosives, we find the two graduating by insensible degrees into each other so that no exact line can be drawn between them. However, most of the explosives known to the arts can be placed with confidence in one or the other class.

Detonating Explosives.—Of the detonating explosives in practical use, the fulminates were the first discovered—this was about the beginning of the present century. At first it was believed that they would play an important part in gunnery, but this notion was dispelled when their nature came to be fully understood. Though the amount of gas furnished by them is small, they explode with great violence. In rapidity of decomposition they probably exceed nitro-glycerin. This gives a peculiar local character to the explosion. Berthelot holds that the pres-

sure generated by the fulminate of mercury on bodies closely enclosing it, is greater than that of any other known explosive. He estimates it at 40,000 kilogrammes per square centimeter, or over 500,000 pounds on the square inch. To illustrate the local character of the explosion—it is said that in the cap factories a man has been killed by a shock which left another almost at his elbow unharmed. The mercury salt is the only one used in the arts. Pure or mixed with either potassium chlorate or nitrate, it is used in making gun caps and primers, and also the caps or detonators employed to explode nitro-glycerin, gun-cotton and other high explosives. For the latter purpose a small percentage of gun-cotton is sometimes mixed with it. It is the best detonating agent we have for the high explosives.

Nitro-Substitution Compounds.—About 1846 a new list of high explosives was given to the world in the discovery of the nitro-substitution compounds, gun-cotton, nitro-sugar, nitro-glycerin, etc. These compounds are formed by the action of strong nitric acid on the organic substances, cotton, sugar, glycerin, etc. The number of nitro-substitution compounds now known to chemists is very great. A large proportion of them are explosive. The reaction by which these substances are formed is a curious and interesting one. Nitric Acid has the formula HNO_3 . In the reaction it is divided into HO and NO_2 . The radical NO_2 is called nitryl. It replaces H in the organic substance acted upon—one molecule of NO_2 taking the place of one atom of H . The atom of H displaced unites with the other part of the nitric acid, that is the HO , to form water H_2O . Many substances are capable of forming several distinct nitro-substitution compounds depending upon the number of hydrogen atoms replaced, or as it is commonly called, the degree of nitration.

Gun-Cotton.—Gun-cotton is the most highly nitrated form of nitro-cellulose. Nitro-cellulose can be readily made from a great variety of substances, such as cotton, linen, jute, vegetable pith, woody fibre, saw dust, etc. Special precautions are required however to make gun-cotton proper, or tri-nitro-cellulose, and

cotton is the best material to operate upon. The lower forms of nitro-cellulose are readily distinguished from the higher by being soluble in ether. The solution of these compounds in a mixture of ether and alcohol is familiar to us all under the name of collodion. It is a well known agent in both surgery and photography.

Camphor is another solvent for the lower forms of nitro-cellulose. This discovery is very interesting as being applied in the manufacture of a substance of great utility and importance in the arts. In the preparation of this, the nitro-cellulose is ground to a fine dust by special machinery and intimately mixed with camphor which has also been reduced to fine particles. Certain inert matters, to give body or color, are also added. When submitted to pressure and a certain degree of heat the nitro-cellulose is dissolved by the camphor and loses all trace of its original structure. The resulting substance is celluloid, or artificial ivory—one of the happiest hits of American inventive genius.

The explosiveness of nitro-cellulose depends entirely on the degree of nitration. The lower forms are almost non-explosive, being deficient in the necessary oxygen. The intermediate forms have been used by various inventors in making explosive mixtures, such as Reeve's gun-felt or Schultze wood-powder. The latter is made by nitrating small cubes of wood and then soaking them in a solution of nitre. This powder was used somewhat on the continent of Europe. In this country the most persistent experimenter in this line is Carl Dittmar. It seems to have been the ambition of his life to make a sporting powder on this principle. He has tried various expedients. His last powder is made—(or rather was made—the writer has heard nothing of it for several years) by punching tiny discs out of wood-pulp cardboard and nitrating these, and then soaking them in a solution of nitre. He has taken out various patents on the subject. One is for parchmenting the discs with sulphuric acid. Those of you who are sportsmen may have tried his powder. The writer has heard of several accidents with it, in which sportsmen have had their guns destroyed and have come near losing their lives. It

is possible that these accidents can be explained by the tendency of nitro-cellulose to detonate under strong confinement.

There is a sporting powder of this kind now in the San Francisco market, called "wood-powder." It seems to be a nitro-cellulose, made from very fine wood-fibre, incorporated with about twelve per cent of nitre and roughly granulated through sieves. It is very light. The color is a brownish yellow. When burned in the open air it leaves a residue of charred matter. In the gun it is said to be very clean. The strength is about equal to gunpowder, volume for volume. No accidents with it have been heard of. It probably owes its safety to the low grade of the nitro-cellulose.

Gun-cotton had the advantage of most of the earlier discovered nitro-substitution compounds, in being susceptible to two different forms of explosion—by ordinary combustion and by detonation. Nothing whatever was known of the latter method of exploding it, but its property of exploding by combustion placed it at once within the experience of the many persons familiar with the use of gunpowder. In the open air a small quantity of it will burn with a quiet flash. Confined in the bore of a gun, it undergoes a combustion which is much more rapid than gunpowder, but like gunpowder the burning may be regulated to a certain extent. It is made slower by spinning the fibre into yarns. Austria made an extensive trial of it for artillery purposes, but finally gave it up for its older rival, gunpowder.

Its history as a blasting agent dates from the use of the detonating cap, which developed energies in it which had never been dreamed of. It has been used extensively in the torpedo service of England and various continental nations. Professor Abel of England, has devoted much time to the improvement of its manufacture. For storage in the arsenals and on shipboard, it is kept wet, in which condition it can only be exploded by a heavy primer of the dry gun cotton. Professor Abel introduced into its manufacture the process of pulping it after nitration, which enables it to be thoroughly washed and purified from the adhering free acids. This pulp is afterwards compressed into hard discs, to give it the density and concentration of power necessary in high explosives.

The only attempt in this country to bring gun cotton into competition with nitro-glycerin for blasting purposes, was made on this Coast a few of years ago, in the establishment of the Tonite Powder Company. Tonite is an English invention. It is composed of pulped gun cotton and barium nitrate, thoroughly incorporated and compressed into a solid stick or cartridge. It is very insensitive to shocks which will readily explode nitro-glycerin powders. Compared with nitro-glycerin preparations, it is deficient in strength, while it is more costly. So far it has not proved a success in this country.

Gun-cotton presents such decided advantages as a ballistic agent, that many attempts have been made to use it in small arms. These advantages are the presence of very little smoke, and but a trifling residue of solid matter to foul the gun. One objection to it is that it attracts and obstinately retains moisture. Its sensitiveness to confinement makes it a dangerous agent. When exactly the same conditions are preserved, its effects are probably more certain and invariable than those of gunpowder. The writer has seen but one gun which used a gun-cotton cartridge successfully. This was a small but very strong sporting rifle. The cartridge was a loose tuft of gun-cotton, tied longitudinally along a piece of wood about the size of a parlor match. The bullet was prevented from compressing the cartridge by resting against the end of the stick when pushed home.

The most noted attempt to prepare gun-cotton like ordinary powder, is that of Punshon, who mixed the pulped material with sugar. This invention received considerable attention in England eight or ten years ago, but little has been heard of it lately. It probably failed because the hygroscopic effects of the gun-cotton were aggravated by the sugar.

In the *Engineering Magazine* in 1881, there was a notice of a new English sporting powder made from gun-cotton and some material which was kept secret. The powder proved very satisfactory in a series of experiments designed by the inventor, Mr. W. T. Reid. This powder has gained some reputation since, but the writer does not know to what extent it has come into practical use. It seems to be simply a mixture of finely ground gun-cotton and nitrates. The conceded advantages of gun-cotton as to absence of residue and smoke, etc., are claimed for it.

Lack of space compels me to pass over a number of interesting explosives, such as nitro-mannite, nitro-glucose, nitro-sugar, tri-nitro-phenol or picric acid and its salts, the picrates, etc.

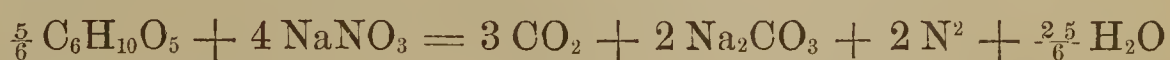
Nitro-Glycerin.—Nitro-glycerin is the most powerful explosive known to the arts. It was discovered by Sobrero in 1846, and was first practically applied as a blasting agent by Alfred Nobel, a Swedish mining engineer. He began his experiments about 1863, but it was not until he discovered that the fulminate cap could be used to explode it, that it became of any value. He established factories for its manufacture in 1866-67, and started an extensive trade in the liquid, which was shipped to all parts of the world. In this country, in 1873 and 1874, the liquid was used quite extensively in the Eastern States. The many accidents attending its transportation and use, led to its abandonment in favor of its powder modifications.

Nitro-Glycerin Powders.—The first and most celebrated of these modifications was Dynamite, or Nobel's Safety Powder, which consisted of a mixture of nitro-glycerin and kieselguhr, a porous infusorial earth, found in Hanover. The principle of dynamite is simple. The absorbent is inert—it adds nothing to the qualities of the powder but safety. By reducing the liquid to a compressible solid, it makes it insensitive to shocks which in the liquid or incompressible form would almost certainly explode it.

Nitro-glycerin powders may be divided into dynamites proper, or powders in which the absorbent is inert, and powders in which the absorbent contributes to the explosive effect. The simplest case of the latter is a mixture of nitro-glycerin with mealed gunpowder. This powder made its appearance very soon after the introduction of dynamite. So little importance was attached to it that the invention was not even patented, and yet it marked a great advance in powder making. The principle of safety is involved in this powder as well as in dynamite proper, while the power developed is much greater than that due to the nitro-glycerin alone, and considerably greater than the sum of the forces of the two ingredients fired separately. In other words the gunpowder is detonated by the nitro-glycerin. It has been shown

by certain French experimenters that the force developed by gunpowder when detonated is a fraction over four times its ordinary power. It is easy to understand this, if we reflect that the nitro-glycerin is exploded in the mixture with the same or perhaps greater facility than in ordinary dynamite, and that it develops an enormous heat—several thousand degrees centigrade—to which heat the gunpowder is instantaneously subjected. Its chemical energies are thrown into extraordinary activity throughout its mass, and its conversion into gas is no longer the result of a progressive combustion in which the chemical reactions rapidly follow each other, but by virtue of a single reaction induced simultaneously in all its particles. Theoretically, the heat and gas developed by the powder is the same as by ordinary firing, but the gases are evolved in a much shorter space of time, and the explosive effect is greatly increased.

This particular powder was followed by others in which the principle was extended to mixtures having the nature of gunpowder, but composed of different ingredients. On this Coast, at the present time, the favorite absorbent for nitro-glycerin is a mixture of sodium nitrate and wood fibre or wood pulp, as it is called. For ordinary gunpowder, wood fibre is a very poor substitute for charcoal. The empirical formula for cellulose, which wood fibre closely approaches in composition is $C_6H_{10}O_5$. We can make a theoretical gunpowder from this by mixing it with a nitrate thus:



But practically this powder will not explode unless strongly confined, and even then its explosion is very feeble compared with gunpowder. When, however, the above mixture is detonated by nitro-glycerin, something like the above reaction takes place, and even more force is realized than from the detonation of gunpowder. We have seen that in gunpowder, potassium nitrate is a better ingredient than sodium nitrate, notwithstanding the greater percentage of oxygen furnished by the latter. In mixture with nitro-glycerin the case is reversed. The heat of the nitro-glycerin more than supplies the quickness naturally deficient in the soda salt.

The writer would say something about another very interesting explosive—Nobel's Blasting Gelatine, but in doing so he would be trenching upon the preserves of another member of this Society, who has made it the subject of special study, and has identified himself with its manufacture in two continents.

Chemistry of Explosion.—The great masters of chemistry have only recently turned their attention specially to explosives, but already some light has been thrown on the subject. We can dimly discern the germs of a theory which may, in the near future, be made to comprehend all the phenomena of explosion.

The energy of explosion resolves itself into the energy of chemical action or affinity, and one of the most careful authorities has said, when we talk of this, "we are venturing into a region which belongs entirely to conjecture, and is, at least at present, altogether beyond the reach of observation." We know, however, that this affinity is elective, and that it changes with temperature, pressure, and other conditions. The source of all chemical energy is in the uncombined, or rather the unsaturated atom. Like the stone carried to the house-top, it has potential energy. Moreover, to continue the simile, we can by chemical processes carry the atom to the very edge of the precipice and yet retain it from falling. When the stone falls under the action of gravity, or the atom unites with another under the action of the mysterious agency we call chemical affinity, its energy is converted into heat, work, or some other manifestation of force. Its energy has disappeared, and to restore its potency, requires the expenditure of the same work (or its equivalent) as developed by its fall. It would seem from this that the heat evolved in the formation of any chemical compound is a measure of its stability, since the same amount of energy must be expended in order to decompose it, and conversely that the same amount of heat or work, if applied, must necessarily decompose it. This speculative reasoning has received something like confirmation from the more recent discoveries in chemistry. It is known that when oxygen and hydrogen unite to form water, an enormous heat is evolved, in fact the greatest amount of heat known to be produced by chemical action for given weights of reagents. But it is

also known that the very stable compound, water, is decomposed into its original elements when subjected to a very great heat.

The great exponents of Thermo-Chemistry have recently divided all substances into two classes, *exotherms*, or those which evolve heat during formation and *endotherms*, or those which absorb heat. Heat of formation of a body is the heat involved in the chemical reaction which produces the body. Exotherms have a plus heat of formation, endotherms have a minus. The latter are comparatively rare, and other things being equal are the most unstable. The most noted example among explosives is nitrogen chloride, which absorbs a great amount of heat in its formation, which is again reproduced in its explosion. In a general sense the heat of formation of a substance is a measure of its stability, but one must not conclude from this that endotherms are necessarily unstable. Every reaction implies either a chemical decomposition or change of physical condition, and the heat of formation is the algebraic sum of the heats involved, which may be plus or minus as the heat of combination is greater or less than that of decomposition. Prof. Cooke thinks that the case of nitrogen chloride can be explained in this way. The reaction for its explosion is as follows:

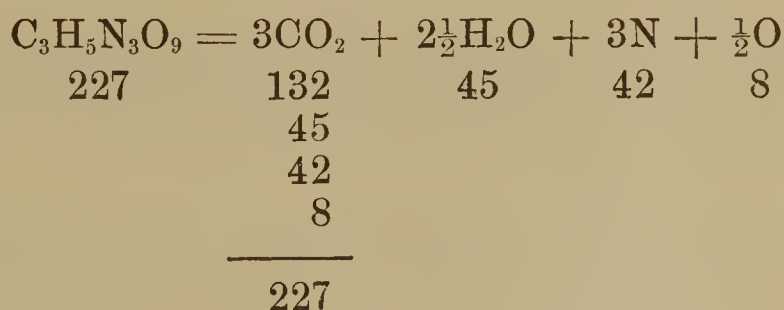


The heat produced is by the union of the nitrogen and chlorine atoms into molecules of each gas—and this heat exceeds that produced by the union of the different atoms into nitrogen chloride by 38,100 units of heat which is the number assigned for its heat of formation. When the explosive is formed heat is produced but it is masked by the greater heat lost by dividing the nitrogen and chlorine molecules into atoms.

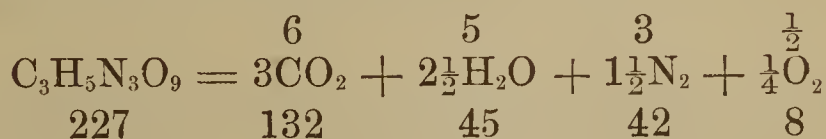
The New Chemistry.—Our study of explosives has been greatly facilitated by the New Chemistry. The chemical equation is now a handy instrument in the hands of the investigator. It tells him at a glance some of the most important properties of an explosive. To make this clear, it will be well to recapitulate a few of the fundamental principles of the New Chemistry. The corner-stone of the structure is Avogadro's law, that equal volumes of all gases under like conditions of temperature and pressure contain the same number of molecules. These mole-

cules are real magnitudes, having both size and weight. They can be best conceived as very minute masses of matter occupying portions of space which are very small compared with the average spaces separating them. The molecules of one gas are small and light, and the molecules of another relatively large and heavy, but the number in a given volume under like conditions of temperature and pressure is the same. From this it follows that the relative weight of the molecule of any particular gas will also stand for the relative weight of the volume. The number of molecules in a given volume has been approximately calculated. One cubic inch of any and every gas contains at the standard temperature and pressure, viz: 0° centigrade and 76 centimeters of mercury— 10^{23} molecules. It is well to remember that the law refers to molecules and not to atoms. A molecule of a compound gas, as HCl, CO_2 , NO, is easy to conceive. HCl is a molecule which contains one atom of H and one of Cl, CO_2 is a molecule which contains one atom of C and two atoms of O. But when we take an elementary gas, as H or O, what does a molecule mean? The molecule then contains two atoms, as H_2 , O_2 , N_2 , Cl_2 , etc. Now we are all familiar more or less with the relative weights of the atoms, $\text{H}=1$, $\text{O}=16$, $\text{N}=14$, $\text{C}=12$, $\text{S}=32$, etc. The weights of the gas molecules will therefore be the double of these numbers $\text{H}_2=2$, $\text{O}_2=32$, $\text{N}_2=28$, etc. Let us adopt as the unit of volume a litre of hydrogen taken at the standard temperature and pressure, 0° and 76 centimeters. It follows from the law, since this volume will contain the same number of molecules of all the gases, that the relative weights of this volume of hydrogen will be 2, of oxygen 32, nitrogen 28, etc. If we take a compound gas, as HCl, it will be 36.5, CO_2 will be 44, etc. In other words the same numbers which express the relative weights of the molecules, will express the relative weights of equal volumes. The symbols for the elements stand for several things. Thus H stands for one atom of hydrogen or 1 gramme, or 1 pound of hydrogen and also for 1 volume of hydrogen; O stands for one atom of oxygen or 16 grammes, or 16 pounds of oxygen or 1 volume of oxygen; CO_2 stands for one molecule of carbon dioxide or 44 grammes of car-

bon dioxide, or two volumes of carbon dioxide. For convenience the weight of a litre of hydrogen at standard temperature and pressure is called a crith and is equal to .09 gramme, very nearly. Taking this as a unit, the relative weights of equal volumes of the elementary gases will be represented by their atomic weights, the relative weights of equal volumes of compound gases by one-half of their molecular weights. The beauty of the theory is brought out by simply constructing our formulas in molecules. Then each gas molecule will represent two volumes of the gas taken at the standard temperature and pressure. Thus the explosion of nitro-glycerin can be represented thus:

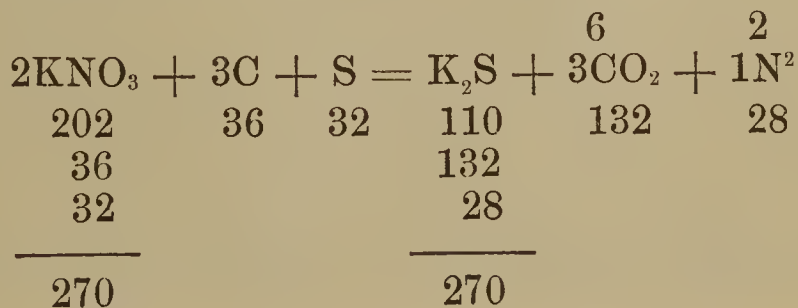


If we change the second member so as to read so many molecules all through, it will read thus:



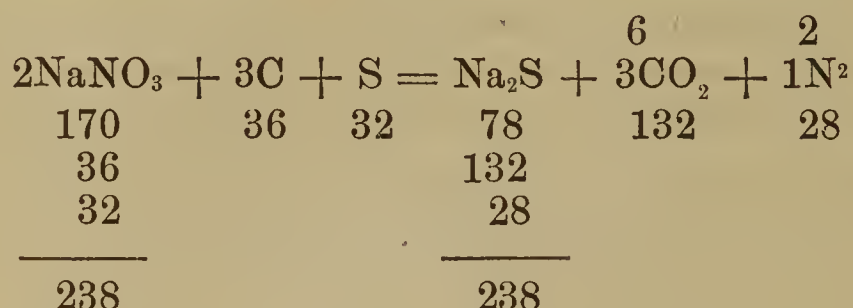
In which we have written the volumes of gas above and the weights below the symbols. If we now take the molecular weights in criths, we see that 227 criths (about 20 grammes of nitro-glycerin) will produce 6 litres of carbon dioxide, 5 litres of water vapor, 3 of nitrogen and $\frac{1}{2}$ litre of oxygen gas, taken at the standard temperature and pressure, $14\frac{1}{2}$ litres of gas in all. We also have the weight of each gas expressed in criths.

The reaction in the case of gunpowder, as usually understood, may be written thus:



That is, 270 criths (about 24 grammes) of potassium nitrate gun-powder will produce 8 litres of gas taken at the standard temperature and pressure. Reducing the quantity to 227 criths to compare it with nitro-glycerin we have 6.7 volumes of gas.

If we take a sodium nitrate powder the reaction will be—



That is 238 criths of the powder ($21\frac{1}{2}$ grammes) will give 8 litres of gas. Reducing as before, we find that 227 criths would produce 7.6 volumes of gas.

Heat of Explosion.—To judge properly the power of an explosive it is necessary to consider something besides the amount of gas. By this term “amount of gas,” we mean the volume of gas reduced to the standard temperature and pressure. The gas has its tension enormously increased by the intense heat produced.

The heat of chemical action has been the subject of much study by eminent chemists of late years. The heat involved in a given chemical reaction is always the same, but unless the conditions remain the same, different amounts may appear as sensible heat, other portions disappearing as physical work. Thus, when CO_2 is formed, exactly the same amount of heat is produced in all cases—but less sensible heat is evolved in burning the diamond, the purest form of carbon, than in burning wood charcoal. In burning the diamond, physical work is performed in disintegrating the material, which work disappears from the heat product. The accurate measurement of the quantity of heat produced by a given chemical action is a problem of great difficulty, chiefly because the chemical change is accompanied by certain physical changes involving heat or work each of which requires to be allowed for before the effect due to chemical action can be rightly estimated. The measurements are made by inclosing the acting substances in a vessel called a calorimeter

surrounded by water or mercury, the rise in temperature of which indicates the quantity of heat evolved by the chemical action. The unit of heat adopted in these experiments is that required to heat one gramme of water from 0°C to 1°C. This unit for convenience is sometimes called a calor. For heat calculations the weights in chemical equations are taken in grammes. The numbers accepted by some chemists for the heats of formation of the compound gases, most commonly present in explosion, are as follows:

$$\text{CO}_2 = 97,000$$

$$\text{H}_2\text{O} = 59,400 \text{ when the product is taken as a gas.}$$

That is 12 grammes of carbon uniting with 32 grammes of oxygen and forming 44 grammes of carbon dioxide will produce 97,000 calors, or will heat 97,000 grammes of water from 0°C to 1°C. The other may be read thus: 2 grammes of hydrogen uniting with 16 grammes of oxygen and forming 18 grammes of steam or vapor, will produce 59,400 calors, or units of heat. But this is not all the heat produced in this case, a portion disappears in converting the water into steam. If the product is taken as a liquid—that is, if we allow the steam to condense—we get in all about 70,000 calors.

This paper has already reached a considerable length, and a consideration of the heat relations of explosives is reserved for a future article; moreover there is a very interesting subject which the writer wishes to notice.

Chemical Theory of Gunpowder.—The chemical equation



has been generally accepted as expressing the chemical theory of a gunpowder explosion, and so far, for the sake of simplicity, we have used it; but when we compare the second member with the actual products of explosion, it appears entirely inadequate. The products of explosion are much more numerous and complex. The following substances have been found among the solid products: potassium carbonate, sulphate, sulphide, hypsulphite, and sulphocyanate, ammonium carbonate, and sometimes free sulphur and carbon. The gaseous products are carbon

dioxide, nitrogen, carbon oxide, hydrogen sulphide, marsh gas and hydrogen. The apparent complexity in this list has been confirmed by the opinion* of Noble and Abel, the celebrated English investigators, who in one of their memoirs have declared that no value can be attached to any attempt to give a general chemical expression to the metamorphosis of gunpowder. They were led to this conclusion by the fact that the same powder seemed to give widely different proportions of the several solid constituents under conditions as nearly the same as possible to attain in experiment.

This discouraging dictum, coming from the projectors of the most thorough set of practical experiments ever made upon gunpowder, has not prevented several distinguished chemists from attempting to formulate a chemical theory for gunpowder. They have preferred to take the mass of facts gathered by Noble and Abel, and treat them after their own fashion. Berthelot, the great French chemist, was the first to assert that one of the products, potassium hyposulphite, did not exist as a primary product, but was formed during the analysis of the powder residue. He proposed several chemical equations, according to which powder might undergo combustion, depending upon the conditions of heat and pressure. If we suppose one portion of the powder to burn according to one equation, a second portion according to a second equation, and the balance according to a third, it is evident we can explain considerable variations in the products of one and the same powder. Berthelot's theory is more curious than useful, and we drop it to consider a much more remarkable and consistent one by an English chemist—Prof. Debus—first published in the transactions of the Royal Society in 1882. We regret that our space is too limited to give more than a brief and inadequate summary of Prof. Debus' paper.

The first difficulty encountered in attempting to apply a chemical theory to gunpowder, is that charcoal is assumed to be pure carbon, whereas it has notable amounts of hydrogen, oxygen and ash, and always contains a small percentage of water. The

*It is no more than fair to say that in one of their subsequent memoirs they have modified this opinion.

hydrogen thus introduced into the powder appears in the explosion as hydrogen sulphide, marsh gas, ammonia, and free hydrogen. Rejecting these products as well as the sulphocyanate, the amount of which is very small, we have, to be accounted for, potassium carbonate, sulphate, sulphide, and hypo-sulphite, carbon dioxide and oxide, and nitrogen.

The plan of analysis followed by Noble and Abel was that proposed by Bunsen and Schischkoff—to determine the amount of sulphide, the aqueous solution was digested with cupric oxide to convert the sulphide into hydrate. The question whether or not the oxygen of the copper compound, during the process, converted the sulphide or part of it into the hyposulphite, was settled in the affirmative by Prof. Debus, after a long and elaborate system of experiments. On this point he says, “the hyposulphite is formed in such quantities that a convenient method for the preparation of the salt might be based on the reaction.” This threw out of consideration one of the products, the presence of which had always been a puzzle, since it is known to decompose at about 450° Fahr.

The point that one and the same powder will give different products of explosion under the same circumstances, is met by our author by showing that the analysis of the products does not agree in many cases with the assumed composition of the powder, and he is forced to conclude that the methods of analysis do not yield exact results, or that the composition of the powder varies from one experiment to another. On this point he says—“Gunpowder is a mechanical mixture of nitre, charcoal and sulphur. It can hardly be expected that such a mixture, even if the greatest care be taken by the manufacturer, will be perfectly homogeneous.” He then gives Noble and Abel’s analysis of two powders side by side with that of a distinguished chemist, showing sharp discrepancies between them. But the best proof that the same description of powder from the same works will vary much in composition, is afforded by Noble and Abel themselves. In their first memoir they assign to rifle large grain powder, carbon 10.86. In their second paper, an analysis of the same powder gives carbon 12.40. These two samples were taken from the same barrel, one from the top and the other from the bottom.

If we will consider the effect that such a difference—more than $1\frac{1}{2}$ per cent. of carbon—would have in the explosion, we will have at once a reason why the relative proportions of carbonate and sulphate should vary from one experiment to another. Indeed, the two powders here considered would have given a quantitative difference in these products almost as great as the greatest difference observed in the whole series of experiments.

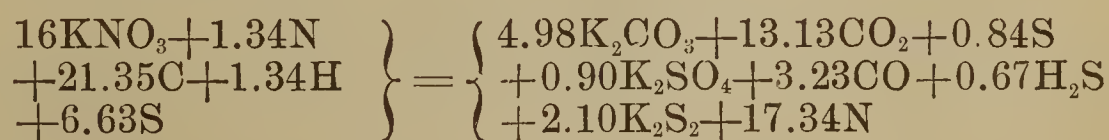
In the experiments of Noble and Abel, the powder was exploded in hermetically closed steel cylinders in quantities varying from 100 to 700 grammes. The products of combustion were thus allowed to remain in contact at a white heat and in a gaseous or fluid state for 60 or more seconds after explosion.

The experiments and results of Karolyi, who fired his powder under different circumstances, when compared with the English, furnish the key to a chemical theory of gunpowder. We get not only an idea of the reactions, but the order in which they follow each other during the combustion.

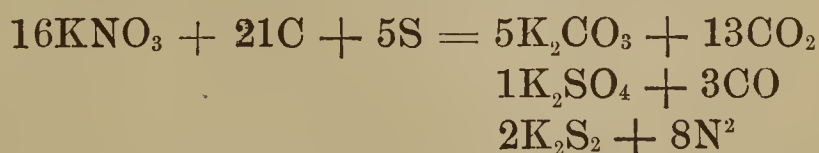
Karolyi inclosed 30 odd grammes of Austrian powder in a small metallic cylinder suspended in the center of a 60-pounder shell exhausted of air and hermetically sealed. The powder was exploded by an electric current. As soon as the pressure reached a certain tension, the cylinder burst, and the products of the explosion were scattered about the space of the exhausted shell. The products were analyzed by the methods of Bunsen. Karolyi found the same products as were afterwards found by the English experimenters, and free carbon and sulphur besides, but the proportions of the several products were very different. Karolyi obtained much more sulphate and less carbonate, while the sulphide found, together with the hyposulphite formed from it during the analysis was insignificant. The English chemists found one fourth of the potassium in the shape of sulphide. A considerable portion of Karolyi's carbon remained unconsumed. As a rule every portion of this element was burnt in the English experiments, though the English powder contained more carbon than the Austrian. Similar differences are observed in the gases. The gases obtained by Karolyi were more combustible; that is, there was more hydrogen and marsh gas and less hydrogen sulphide. The natural conclusion is, that the combustion of Karo-

lyi's powder was interrupted before its completion, and the correctness of this view is sustained when we consider what would have been the result if the products of Karolyi had remained in fluid contact for some time at a red heat, instead of being suddenly cooled and in great part congealed by contact with the cold walls of the iron shell. The free carbon and hydrogen and the constituents of the marsh gas (CH_4) would have been burned at the expense of the oxygen of the sulphate, and the quantity of the latter diminished, sulphide being produced in its stead. The free sulphur would have decomposed the carbonate with the production of sulphate and sulphide, and in short the products would have arranged themselves in the proportions we find in the Noble and Abel experiments.

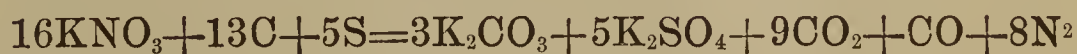
After making various corrections, Prof. Debus deduces the following equation to represent the mean of the results obtained by the English experimenters, in which the composition of the powder as represented by the first member is calculated from the products of explosion—



Rejecting the nitrogen and hydrogen in the first member and part of the sulphur, some of which was found united with the iron of the apparatus, we can simplify this as follows:



The equation deduced for Karolyi experiments, if we reject the free sulphur and carbon, is

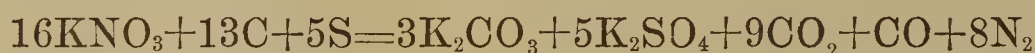


The Austrian and English powders do not differ very much in composition. This last equation represents, therefore, the first stage and the one above it, the completed combustion of gunpowder. Prof. Debus sums up his result as follows:

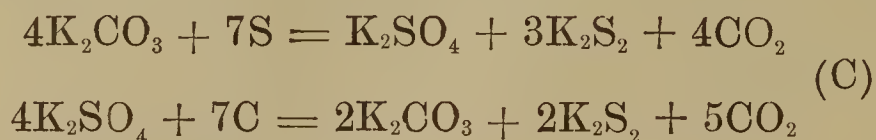
“ The combustion of gunpowder accordingly consists of two
“ distinct stages: a process of oxidation which is finished in a

“ very short time, occupying only a very small fraction of a
 “ second, and causing the explosion, and during which potassic
 “ carbonate and sulphate, carbonic acid, some carbonic oxide
 “ and nitrogen are produced, and a process of reduction, which
 “ succeeds the process of oxidation and requires a comparatively
 “ long time for its completion. As the oxygen of the saltpetre
 “ is not sufficient to oxidize all the carbon to carbonic, and all
 “ the sulphur to sulphuric acid, a portion of the carbon and a
 “ portion of the sulphur are left free at the end of the process
 “ of oxidation. The carbon so left free reduces during the sec-
 “ ond stage of the combustion, potassic sulphate, and the free
 “ sulphur decomposes potassic carbonate. Hydrogen and marsh
 “ gas, which are formed by the action of heat upon charcoal,
 “ likewise reduce potassic sulphate and some hydrogen com-
 “ bines with sulphur, forming sulphureted hydrogen.”

Prof. Debus supposes all gunpowders to burn according to the equation—

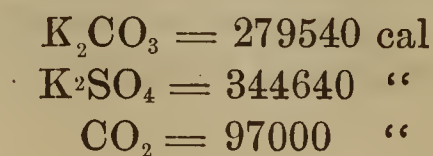


This represents the first stage, that of oxidation. If the composition be such (as is generally the case) that there is free sulphur and carbon left at the end of this stage, and the combustion is not interrupted, then the second stage is represented by the following:



His arguments in favor of Equation (B) are very strong. It happened that Karolyi used two powders—a rifle and a cannon powder—the latter of which contained 3 atoms more of sulphur for every 16 molecules of nitre, yet the products produced during the first stage from the two powders were almost identical and those represented by Equation (B).

The heat relations of the principal products in Equation (B) are remarkable. If we assume for the heat of formation of the carbonate, sulphate, and carbonic acid, the following values:



which are given on the authority of Thomsen, we obtain—

$$3 \times 279540 = 838620$$

$$5 \times 344640 = 1723200$$

$$9 \times 97000 = 873000$$

$$\text{Now } 838620 : 1723200 :: 873000 = 1 : 205 : 1.04$$

or nearly 1 : 2 : 1

ratios, which are very remarkable.

If Prof. Debus' reasoning be correct, equation (B) represents not the strongest but the most combustible mixture that we can make. There being no free carbon or sulphur left in the products it should give a quick, sharp, clean explosion—the properties required in sporting powders. If we make an allowance of four per cent for the hydrogen, oxygen, ash and moisture contained in gunpowder, and calculate the first member of equation (B) to 100 parts, we get for the composition of an ideal sporting powder:

Nitre	80.31
Sulphur	7.95
Charcoal	11.74
	<hr/>
	100.00

The exact composition of high grade sporting powder is one of the most precious secrets of the manufacturer; still several noted powders cited by Prof. Debus closely approach the above formula.

The equations (C) representing the second stage of the combustion of certain powders are worthy of study. In the first place, if we calculate the heats of formation we find that these reactions are endothermic. Heat is consumed and not evolved by them.

This heat lost is converted into mechanical work in the evolution of gas. It seems to me, and I do not wish to make Prof. Debus responsible for the idea, that this point deserves special consideration. This stage consumes more time and is seldom completed except under such exceptional circumstances as those which obtained in the hermetically closed cylinder of Noble and Abel. The effect of these endothermic reactions in gunnery

practice must be to render the explosion less violent—to temper in a measure the brutal character of the blow.

By Prof. Debus' figures, a powder containing $16\text{KNO}_3 + 21\text{C} + 7\text{S}$, which represents approximately service gunpowders, will have 8C and 2S, which will not participate in the oxidizing stage of the explosion—for the time being therefore nearly eight per cent of the powder will act as so much dead matter to impede and retard the combustion of the rest. When the violence of the blow is partially expended this eight per cent will react upon the products first formed, and by a conversion of heat into mechanical work will prolong the action upon the projectile.

We have seen that the sharp, quick nature of sporting powder is largely due to its composition, the characteristic of which is a large proportion of nitre. In blasting powders the case is reversed and the carbon and sulphur are largely in excess. The effect of this composition is seen in the slow, lifting character of the powder as contrasted with sporting. The proportion of carbon and sulphur left out of the first reaction is so considerable that the shock is no longer a sharp blow, but rather a pushing or lifting effect which is extended over a considerable period of time by virtue of the large amount of gas contributed by the subsequent reactions.

The subject is one which should be studied in connection with the preparation of powder for heavy guns.

Professor Debus' paper has been reprinted in this country by the U. S. Naval Institute and can be found in No. 23 of its proceedings. Whether regarded simply as an example of deductive reasoning, or as the most valuable contribution to the theoretical chemistry of gunpowder ever published, it is equally admirable.

TECHNICAL SOCIETY OF THE PACIFIC COAST.

INSTITUTED APRIL 1884.

PROCEEDINGS.

(VOLUME II — APRIL, 1885.)

MINUTES OF MEETINGS.

REGULAR MEETING.

April 3, 1885.

President Mendell in the Chair.

Minutes of the preceding meeting were read and approved.

Wm. H. Radford was proposed as a non-resident member by Aug. J. Bowie, Jr., L. L. Robinson and Sanford Robinson.

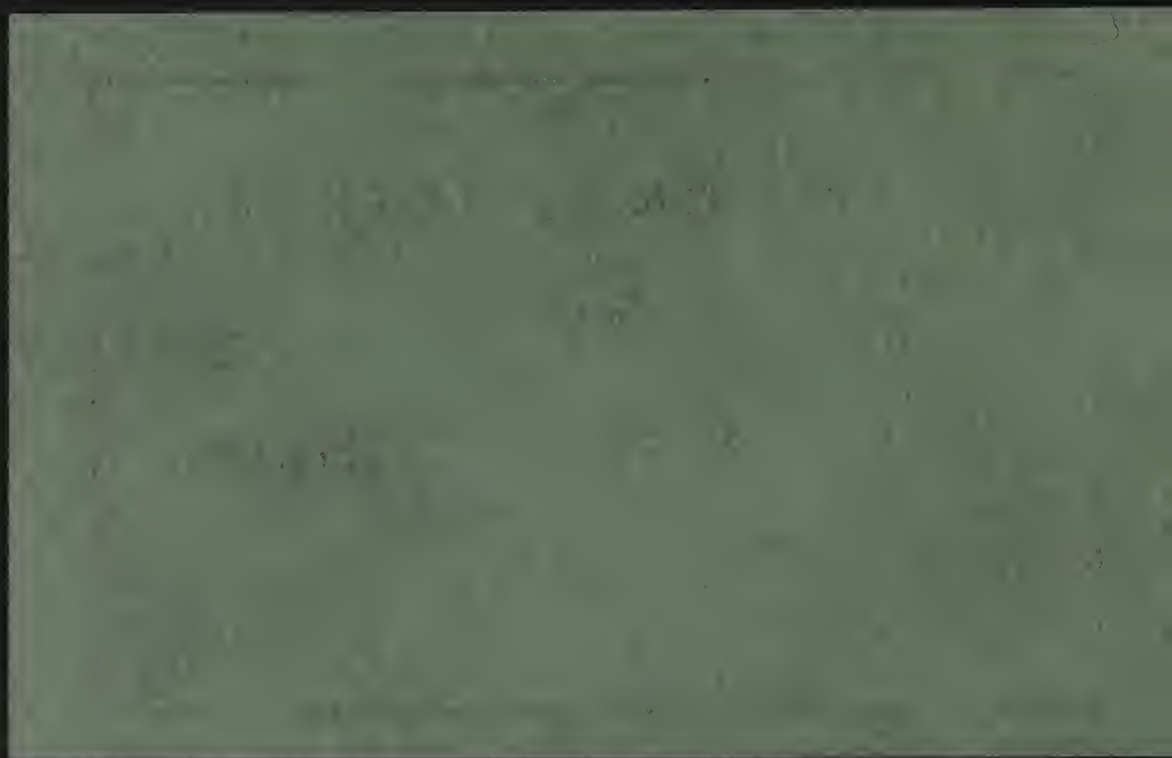
A paper by Wm. R. Quinan, entitled "A Talk About Explosives," was read.

NOTES ON EXPLOSIVES

BY

PROF. CHAS. E. MUNROE,

U.S.N.A.



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